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ELEMENTS

OF

CHEMISTRY.

BY

JOHN WEBSTER.

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TO THE

MEMBERS OF THE SOCIETY OF

SCHOOLMASTERS,

THIS ELEMENTARY WORK

IS RESPECTFULLY DEDICATED;

NOT ONLY AS A TESTIMONY OF PERSONAL ESTEEM,

BUT LIKEWISE AS

A TRIBUTE DUE TO THEIR UNWEARIED LABOURS,

IN PROMOTING THE DEAREST INTERESTS

OF THE RISING GENERATION,

BY THEIR OBLIGED SERVANT,

JOHN WEBSTER.

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PREFACE.

A FEW observations will be necessary to explain the motives which induce the Author to offer an elementary work on a subject that already possesses so many advantages of this kind. It is but justice to state, that it was not produced in the mere spirit of Bookmaking, nor in the presumption that the general principles of Chemistry are better displayed in this work, than in many others which have already been published. Its real object is to aid the exertions of the Author as a public lecturer amongst a juvenile class of auditors in many of the most respectable seminaries.

In an extensive subject, like that of Chemistry, it is hardly to be supposed that young persons, whose minds are occupied by other studies, can retain a connected view of the whole subject of a Lecture of which they have no previous knowledge; it therefore becomes highly advantageous, not only to prepare them for what they are to hear, but likewise to give them a means of reverting to the subject afterwards, the more effectually to impress it on their minds. This, it is apprehended, cannot be better done, than by supplying them with a work in which the subject stands in the same order as the lectures delivered.

It is presumed that this general outline may likewise be found useful to those at a more advanced period, who may not have had an opportunity of paying much attention to chemical subjects, yet are desirous of taking the advantage of public lectures, to promote their knowledge in the laws and operations of nature.

A plan, similar to the present has been adopted, with respect to natural philosophy: an elementary book on this subject, has already met with considerable success; but as it embraces only a part of the subjects which are delivered in the Lectures, it becomes the more necessary to give a general view of the whole, by adding the present publication.

Elements of Chemistry.

INTRODUCTION.

IN a philosophic point of view, the operations of nature, as far as they are known to man, may be divided into two parts. *Mechanical* and *Chemical.* Mechanical as relating to the effects produced by matter and motion; and Chemical as referable to those spontaneous changes which are perpetually taking place amongst the ultimate or constituent particles of matter.

If a stone be let fall, it descends by the power of gravity, and with a momentum or force, according to the mass of matter multiplied into its velocity. Or if a ball be discharged from a cannon, it will take a direction compounded of the projectile force of the gunpowder, and the influence of gravity.

These laws of nature operating on masses, have no relation to the principles of the elements employed in forming those masses.

They are to be considered as purely *mechanical;* equally relating to the revolutions in the planetary system and the most extensive operations of nature, and to the construction and action of every mechanical machine.

All mechanical power or advantage arises from a difference of velocity between the acting and resisting forces; the momenta of which are compounded of matter and motion.

In the construction of a Clock; the moving power is obtained from the gravity of the weight, the equal division of time from the vibration of the pendulum, and the quantity of motion from the wheel work; all of these are mechanical operations, and equally dependant upon matter and motion; but it is far otherwise with the chemistry of nature:—here is no regard to the quantity of matter, nor to the influence of velocities.

All *chemical* effects arise out of the changes that take place amongst the integrant or constituent particles of matter; which changes are produced by the different electrical capacities of these particles.

If a piece of sugar be thrown into a glass of water, this solid mass speedily disappears, and the transparency of the fluid is not altered. Here some peculiar operation must have taken place between the two bodies, otherwise the cohesion of the particles of the solid would not have been overcome, and these particles so minutely separated from each other, and equally distributed throughout the fluid as not to impede the transmission of light. This effect is now attributed to the different electrical states of the two bodies, by which means the opposite particles are united in restoring the electrical equilibrium.

Chemical or electrical affinity not only brings opposite bodies together, but the combination frequently exhibits properties totally different from those of the bodies of which it is composed: for instance, the common salt, which is so plentifully used, is formed by the chemical union of muriatic acid and soda. These bodies in their respective states are highly corrosive, and would soon produce fatal effects if they were poured separately into the stomach; but united by chemical agency, they produce a harmless mass, which is agreeable to the palate, inoffensive to the stomach, and highly useful in antiseptic processes.

It is under this mechanical and chemical view that we investigate the procedure of nature, and render her operations useful to man. The laws of *Mechanics* have been clearly defined and well understood for some centuries past: but *Chemistry*, an equally important part of the volume of nature, is even at the present hour but imperfectly known. It is more than probable, that since the creation of the world to the middle of the last century, this subject has never been the object of scientific enquiry, or treated in any way worthy of its great utility; whether we consider its influence in the arts and manufactures of every enlightened country, or view it as one of the great operations of nature, which displays the admirable contrivance and infinite wisdom of the Deity.

There are but few of the arts in which chemical agency does not interfere. In some of the following, success must in a great measure depend upon the degree of chemical knowledge that is employed. Of this description are Dying, Bleaching, Calico printing, Brewing, Wine making, Distilling, the making of Vinegar, Soap, Glass, Tanning, &c. The conversion of earth into the most beautiful porcelain, and the reduction of ores into metals, which are so usefully and extensively employed, depend entirely upon chemical processes.

Many of these arts are of great antiquity; but this affords no proof of the early existence of Chemistry as a Science. The excellence of many ancient manufactures, must rather be attributed to chance, than to any systematic knowledge of chemical principles. Wine is mentioned in holy writ, as being produced at a very early period; but the spontaneous operations of nature would alone be sufficient to form this liquor. Thirst, one of the most urgent necessities of man, would be gratified by the agreeable and refreshing juice of the grape; and as this could not be obtained at all times, it is reasonable enough to suppose, that he would express this juice to serve him when the season might not offer the fruit for his refreshment. The time of expressing the ripe fruit is at a period when the solar heat induces a fermentation, which speedily converts the saccharine substance of the grape into alcohol, a pungent, ardent, intoxicating fluid; and this natural process, it would seem, did not render the beverage less agreeable to our forefathers.—Thus may have arisen the production of wine.

Many other arts known to the ancients,

may, in a similar manner, be attributed to the spontaneous changes of nature, or to a kind of chance, produced by jumbling together different ingredients, in the pursuit of objects very foreign to the discovery.

The arts and sciences had, no doubt, made considerable progress amongst the Egyptians; but our ignorance of the characters of their language, renders useless the records of their knowledge.

The historic accounts of the subsequent Greek and Roman states, shew us, that their information in the operations of nature, was of a very imperfect and limited kind; although the valuable remains of classical science, eminently prove that literature was at these periods in the highest state of exaltation. Of chemistry we have not a single word; and as to natural philosophy, saving some mechanical principles of Archimedes, we have nothing worthy of our attention. Thus, shut out from a knowledge of Nature's laws, they were unable to trace the Deity in his works, and were therefore imperfectly informed of a Divine Being, until a Saviour manifested his Omnipotence in the redemption of the world.

Chemistry may date its birth from its spurious parent Alchemy. The Arabians first became infatuated with the ridiculous notion, that all matter was resolvable into Mercury, and that Mercury might be transmuted into Gold, the purest state of matter, from which a fluid might be obtained that would preserve the human body from disease and death. These absurd notions rapidly spread through different parts of Europe, and an infinite number of experiments were tried to effect the desired purpose:—it is hardly necessary to say, that these experiments met with the fate they deserved.

From the attempts of the Adepts, (as these experimenters were called,) in the combination of various materials, different effects were produced, which were fortunately recorded. When the fury of Alchemical pursuits had subsided, these investigations obtained more sober consideration; certain analogies were noticed and arranged; and we may fairly date the commencement of chemical science from this æra.

But this period, in Europe, was unfavourable to scientific pursuits; Bigotry and Superstition, those enemies of true Religion, were equally the enemies of science; and it would have ill befitted the interests of the religion of that day to suffer mankind to exercise their reason in the laws of nature, or investigate in them, the beneficent Attributes of the Deity. The interest of the church was to establish a political standard of faith, and every departure from this standard was to be considered as a heresy that merited the severest anathemas and torments.

The following example will illustrate this assertion: The transcendant talents of Copernicus, had illuminated Europe with his sublime theory of the Solar System. The philosophers of the age were struck with the beauty and sublimity of his principles. Galileo, a man of no common understanding, led on by the radiance of truth, propagated the Copernican system amongst his disciples, and refuted the principles of Ptolemy, who had established the absurd doctrine, that the earth was the centre of our system, and that the sun, and the planetary bodies, revolved round it.

This daring innovation called for the vengeance of the Church, and Galileo was summoned to appear before the holy inquisitors to answer for his heresy. Personal consideration overcame the influence of truth, and this great philosopher fell. He declared that he did not believe the Copernican principles which he had promulgated, and signed a solemn denial of his former opinion, which was immediately sent forth to reclaim the professors of truth and reason; whilst the unfortunate Galileo, pining with grief for his pusillanimous conduct, died of a broken heart.

But, to return to our brief history of Chemistry; we find this subject assuming something of a scientific appearance, under the talents of Boyle, Hooke, Mayow, Boerhaave, and Newton; which was afterwards greatly improved by Euler, Leibnitz, and Sthal: but it is only within the last fifty years that we are to look for the regular organization of chemical science.

The researches of Priestly, Black, Craufurd, Cavendish, Scheele, Lavoisier, Fourcroy, Berthollet, and many other equally meritorious chemists of the English, French, and German nations, have laid the solid foundation on which the science now rests; but the superstructure was reserved for the unequalled talents of our countryman, Professor Davy; nor should the aid supplied by the unwearied application of Gay-Lussac, Thenard, Hatchett, Allen, Henry, and many others, be forgotten.

The bright aspect of the present, foretels our future success; and we may close these introductory observations, with the probable and early expectation of very important chemical discoveries. In Europe, bigotry and superstition are daily sinking into oblivion; the mild and benignant principles of true religion, are opening the way to a liberal and enlightened policy which establishes man in his rational liberty; divests him of the fear of persecution, either in a religious or political point of view, and leaves him the full exercise of reason in investigating those laws of Nature, which the Deity has implanted for his use and improvement. The progress which has already been effected, under this sacred sanction, within a few years, is a strong guarantee for what we have a right to expect; and we have now this important satisfaction, that since the creation of the world to the present moment, the admirable book of Nature has never been so fairly displayed to the rational and inquisitive mind.

Chemical Affinity.

TILL within a short period, chemical attraction, like the attraction of cohesion, or universal gravity, was seen, but not understood. The different compositions and decompositions were attributed to an inscrutable operation of nature: but the intelligent and penetrating mind of Mr. Davy, has unravelled this mystery; and numberless experiments now prove to us, that chemical affinity is nothing more than electrical attraction.

It has been long observed, that different bodies have greater or less capacity in conducting the electrical fluid, and this conducting power is supposed to arise from the disposition of the body itself for electricity. Hence, it has been concluded, that this universal fluid resides in different quantities, in different bodies, and that a body is capable of changing its quantity under different circumstances; which, consequently, changes its conducting capacity.

Iron, for instance, is a good conductor of electricity, in its metallic state; but becomes an imperfect conductor, in the character of an oxide, that is, when the metal is united with the elementary body, oxygen.

Glass, which is a non-conductor of electricity, becomes a good conductor, when it is heated to 400 of Fahrenheit's thermometer; and water, which is an excellent conductor in its fluid state, is a non-conductor in its frozen state.

From these and many other changes which are produced by what are called chemical agencies, Mr. Davy was led to suspect that these agencies, or affinities, were not the cause, but merely the effect of electrical changes; and that all chemical combination is produced by the different states of electricity possessed by the bodies previous to their union.

These very important and interesting opinions have been satisfactorily confirmed by numberless experiments with the Voltaic Apparatus, or, as it is still called by some, Galvanism.

Suppose two bodies, possessing different electrical capacities, have their ultimate particles brought near to each other by solution; from the positive and negative state of the particles, they will unite by electrical attraction, and the action between them will cease: but if the force which unites these two bodies be overcome by a superior electrical influence, the particles will separate again, and a second combination take place.

For example, suppose the acetate of lead (which is a salt produced by the chemical union of the acetic acid, or vinegar with lead,) be dissolved, and exposed to the influence of the voltaic electricity, we immediately obtain the lead in its metallic state.

The principle by which this is effected is as follows: Oxygen, which is the cause of acidity, and forms a considerable portion of the salt, possesses a negative electricity: the lead is a metallic inflammable body, existing in a state of positive Electricity; these unite by electrical attraction, and form the salt; but when a solution of this compound body is subjected to the action of the voltaic trough, one end of which gives out positive electricity, and the other negative, the positive end of the apparatus having more influence, or being in a higher state of electricity than that of the lead, the acid leaves its inferior combination and flies to the superior; deoxygenizing the lead, and leaving it in its original metallic state.

The same principle is pleasingly illustrated by a solution of sulphate of copper, or blue vitriol. As soon as the electric wires are brought into the solution, the copper, in its metallic state, begins immediately to form upon the negative wire.

The following experiment of Mr. Davy is peculiarly demonstrative of his important discovery.

If a solution of sulphate of iron, or green vitriol, as it was formerly called, be put into one glass, the fluid alkali, ammonia, or spirit of hartshorn into another, and pure distilled water into a third, and they be placed in this order between the two extremities of the voltaic apparatus, bringing one wire of platina from the positive end, into the water, and another from the negative end, into the solution of sulphate of iron, the intermediate vessel which contains the ammonia, being connected with both the others by means of a piece of asbestos, it will be found that the sulphuric acid contained in the sulphate of iron, will pass through the whole mass of the ammonia, for which it has a powerful affinity, without the least combination, and form itself at the end of the positive wire in the distilled water, which in a short time becomes acidulous. This very satisfactorily proves that chemical and electrical affinity are the same, and that chemical combinations solely depend upon the different states of the electric fluid which resides in bodies.

To obtain chemical combination between two bodies, it is necessary that one of the two, at least, should be in a fluid state.

When two or more bodies chemically combine, the temperature changes at the moment of combination. When the temperature is increased, and heat is given out, the ultimate particles of the bodies are brought nearer together, and the compound tends towards solidity. When the temperature is diminished, it is exactly the reverse; the sensible heat becomes latent; the particles of the bodies are further separated by it, and the mass tends towards fluidity. The Chemical affinity between two bodies becomes weaker and weaker as they approach towards saturation. The first portion of salt put into water unites with it more powerfully than the second; the second than the third, and so on, until the water is saturated, or will hold no more in solution; after this, any additional quantity of salt falls in an undissolved state to the bottom.

Chemical compounds acquire new properties, and frequently vary in consistence, smell, colour, form, and effect from the separate bodies of which they are composed. Muriatic acid and Lime have each a very corrosive taste: the acid reddens vegetable blues, and the lime turns them green; but when united they produce no effect upon vegetable colours; lose their corrosive taste, become intensely bitter, and form a chrystallized salt, called muriate of lime.

To a solution of muriate of lime, which is clear and colourless, if a few drops of a solution of potash be added, the lime will be precipitated and fall in an insoluble mass to the bottom of the vessel, which is again taken up on pouring in a small quantity of dilute sulphuric acid.

This is a good example of simple chemical affinity. The muriate of lime is formed by the negative state of the acid united with the positive state of the lime; but the potash being in a higher state of positive electricity than the lime, the latter is displaced or thrown out of its combination with the acid, which becomes occupied by the alkali till a small quantity of sulphuric acid is thrown in; this seizes on the potash, and suffers the lime to unite again with the muriatic acid.

There are many other entertaining and interesting experiments to explain this theory; but sufficient has already been said to give a general idea of the subject; a few more will however be mentioned, merely as a matter of amusement.

To a solution of carbonate of potash, pour a small portion of sulphuric acid, and an abundant quantity of carbonic acid gas will be set free.

Take a solution of nitrate of copper, and add to it a solution of potash, the copper will be immediately precipitated.

Take a very dilute solution of nitrate of copper, and pour into it a small quantity of liquid ammonia; a beautiful blue colour will be instantly produced, which may be again destroyed by a few drops of sulphuric acid.

If tincture of galls be poured into a solution of sulphate of iron, common writing ink is immediately formed: this may be decomposed, and the fluid again rendered colourless by adding a few drops of sulphuric acid.

If sulphate of soda be rubbed in a mortar with nitrate of ammonia, the two solid masses will speedily unite and become fluid.

If a saturated solution of muriate of lime be poured into a saturated solution of potash, or soda, a solid mass will be instantly formed from their union.

Chrystallization.

THE term chrystallization is here only intended to express the aggregation of the particles of salts which are held in solution by a fluid. This aggregation is produced by the attraction of cohesion, and is an effect directly the reverse of that which produces the solution of salts.

Take a saturated solution of sulphate of soda, or Glauber's salt, boiling hot, and completely fill a glass bottle with it, then tie over the mouth of the bottle, a piece of bladder, and let it stand to cool. When the temperature of the fluid is reduced to that of the atmosphere in which it is placed, cut the bladder, and the process of chrystallization will immediately commence. By this means, in a few seconds, the saturated fluid will be converted into a solid mass of chrystals.

The principle appears to be as follows: The affinity between the water and the salt is aided by the influence of heat; which dissolves the greatest quantity possible of the salt; in this state the fluid is covered over, and as the temperature diminishes, the bulk diminishes, and the atmospherical pressure is kept off from the surface, by the bladder which covers the neck of the bottle. At the temperature of the atmosphere, the attraction of cohesion amongst the particles is not sufficient to overcome the separating influence of the caloric contained in the fluid; consequently, the mass remains in a fluid state: but if a hole be made in the bladder, the atmospherical pressure instantly acts in aid of the attraction of cohesion, by pressing the particles towards one another. Under these circumstances, the attraction of cohesion becomes greater than the opposite influence; a considerable quantity of heat is evolved, and the particles of the salt aggregate, forming regular chrystals.

Different salts chrystallize in different forms, but the same salt, however frequently it may be dissolved, will always resume the same figure.

The principle under which this arrangement is formed, has long been a subject of considerable interest, and has recently been greatly elucidated by the labours of the French chemist, Häuy.

There are a considerable number of salts, consequently a great variety of regular chrystalline figures; and when we reflect, that the particles of the different salts of which these chrystals are formed, were minutely distributed throughout the solution, it will excite our admiration that they should invariably take the same arrangement, so that each salt may immediately be known by the form of its chrystal; yet thus beautifully regular are the laws of Nature.

Caloric, or the Matter of Heat.

THIS part of our subject, is of all others the most interesting, and deserving of particular consideration: great progress has already been made, but still our most approved theories leave many of the phenomena of heat unexplained.

The great importance of Caloric, or the principle of Heat, will readily be admitted, when we look round into the great mass of created matter, and find this subtile fluid diffused throughout every part. From its universality, it is evident that it is intended for great and important purposes; and seeing that bodies assume different bulks, under different quantities of active heat, it is reasonable to suppose that to its potent influence, matter is indebted for many of its modifications; and that bodies have different specific gravities, according to the quantity of latent heat which they naturally possess.

The power of attraction is that universal influence by which the particles of matter are united, and solids are formed: this power, modified by the opposing influence of heat, may not only give to different masses their peculiar constitution, but the changes of capacity for heat may produce every chemical operation in nature; and experiments sufficiently shew, that all chemical combinations are accompanied by changes of temperature.

Independently of these two important agents, Attraction and Caloric, there is a third to be considered, which is the pressure of the atmosphere.

This elastic fluid, which surrounds the earth to a considerable height, is acted upon by the power of attraction, according to the quantity of matter, in common with all other bodies.

The gravity, or pressure, with which the atmosphere acts on the surface of the earth, amounts to about fifteen pounds on every square inch: this pressure serves as an intermediate power between the opposing influences of attraction and caloric.

It is to the weight of the atmosphere we are indebted for many fluids, particularly water; for if no other power existed besides attraction and caloric, as soon as ice became liquified by heat, it would instantly pass into the state of vapour.

The solid state of water, or ice, is produced by the force of cohesion and the abstraction of heat: but as ice is supplied with caloric, the power of cohesion is diminished, till at length the particles are so far removed as to lose their fixity, and form a fluid. From this state, it would instantly pass into vapour, if it were not retained by the pressure of the atmosphere; for the power of attraction being overcome, the particles of the fluid would immediately obey the separating influence of heat, and be driven to a prodigious distance asunder; but the atmospherical pressure aids the force of attraction, and although the attractive influence is so far overcome by caloric as to produce a dense fluid, yet its diverging force is restrained by the pressure of the atmosphere, until a sufficient accumulation of heat be obtained to overcome this additional power.

If we take ice and place it in a vessel over the fire, the ice will begin to melt, but the melted fluid will be as cold as the ice, until the whole is dissolved. For, as fast as the heat enters, it seizes on a portion of the solid; liquifies it, and becomes latent in the fluid which is formed. A certain quantity of heat is essential to form or constitute a fluid; nor can fluidity exist without it. The whole of the ice being melted, any additional quantity of heat becomes active or sensible, and the temperature is increased to a certain extent, under the pressure of the atmosphere, without altering the state of the fluid. But this point being obtained, the atmospherical pressure can no longer restrain the effects of this accumulated heat, and the water is instantly converted into steam; a highly elastic vapour, 4000 times lighter than water.

This general theory is interestingly confirmed, by taking a jar of water, about milk warm, and placing it under the receiver of an air pump; as soon as the atmospherical pressure is withdrawn, by exhausting the air, ebullition instantly takes place, and steam is copiously given out.

All bodies change their bulk as their temperature changes.

The preceding observations shew that water exists in the solid, fluid, or gaseous state, varying its bulk according to the different degrees of heat: the same principle applies generally. Metals can exist in a solid, fluid, or gaseous state, and with increase of bulk, according to the increase of heat. Even a bar of iron will vary in its size as the atmospherical temperature varies, and its dimensions will be greater in summer than in winter.

Quicksilver was long considered as a permanently fluid metal; but, by a certain privation of heat, it becomes solid and malleable, like other bodies, and its bulk increases as the temperature increases, until it is converted into a gaseous state.

There are some bodies in which these various changes cannot be produced; but this must not be used as argument against the general expansion of bodies by heat: it only shews our ignorance or inability in operating upon them. Clay may seem an exception to the general principle, as it contracts by heat; but this arises from the chemical changes that take place amongst the particles of the body. By burning, clay undergoes a semifusion, and the arrangement of its particles is entirely changed.

Mr. Wedgwood formed an instrument, called a Pyrometer, for ascertaining high temperatures, by the contraction of baked clay.

The bulk of water is increased when frozen, which arises from the arrangement of the particles, in the act of chrystallization.

From the fluidity of quicksilver, and its regular expansibility under different degrees of heat, it is employed in forming the thermometer. Fahrenheit, the inventer of the thermometer most generally employed in England, constructed it in the following manner: He took a glass bulb and tube and filled it with quicksilver, he then exposed it to the greatest degree of heat the quicksilver would bear, without passing into the state of vapour, and hermetically sealed the end of the tube: it was afterwards placed in the greatest degree of artificial cold that could be produced; this formed the whole range of his scale, which was divided into 600 parts. When the thermometer was placed in water just beginning to freeze, the quicksilver stood at the 32d division, and in water just beginning to boil, at the 212th, which are called the freezing and boiling points. Water does not invariably boil at 212 degrees; this depends upon the state of atmospherical pressure: when the

Barometer stands at 31 inches, water will not boil until it has obtained a temperature of about 215 degrees; and at the height 28 inches, it will boil at 209 degrees.

The present mode of constructing the Thermometer, is, by placing the bulb and tube in boiling and freezing water, and dividing the distance between these two points into 180 divisions.

Concerning the nature of heat, a greater variety of opinions have been offered than, perhaps, on any other subject in natural philosophy: we cannot examine it in a detached state; it is presented to us in perpetual combination, and with effects as variable as the bases with which it is united.

Some of the earlier chemists supposed heat to be generated by the vibration or motion of the particles of bodies amongst themselves, and thus to be a mere quality of matter. A piece of iron is made red hot by hammering it on an anvil. Two pieces of wood may be rubbed together till they set each other on fire. A flint, also, striking a steel, detaches pieces of red hot metal. These, and similar experiments, were supposed to be produced by the action of the particles of matter amongst one another.

Boerhaave appears to be the first who conjectured Heat to be an independent body universally diffused, but varying in quantity in different bodies. Further enquiry confirms this supposition, and in the present æra of chemical science, little doubt remains on the subject.

The sun is the source of light and heat; but whether light and heat are modifications of the same thing, or two distinct bodies capable of combination, is a question not yet determined.

Some have supposed that light is heat in a projectile state; or that heat, accumulated to a certain extent, flies off in the character of light, and that the projected particles may exist at such distances from one another, that a sufficient quantity cannot be united to produce any sensible heat, although we are sufficiently impressed with the sensation of light.

It is however, by much the more general opinion, that light and heat are distinct bodies, proceeding in combination from the sun, and governed by the same optical laws.

The general importance of heat and light in the economy of nature, is sufficiently obvious.

If a healthy plant be partially excluded from light, it soon loses its verdant appearance, and becomes pale and sickly: if it be totally secluded, death will ensue, although it be supplied with heat, air, water, and every other element of vegetation: yet, even in this situation, if the light of lamps be supplied, vegetation will be continued with considerable vigour. The effects of heat on vegetation require no comment.

The following experiment seems to prove that heat radiates, and is governed by the same optical principles as light: Place two concave mirrors, about twelve inches in diameter, opposite to each other, and at the distance of ten or twelve feet asunder; let a piece of warm iron be placed in the focal point of one reflector, and a thermometer in the focal point of the other; the radiation of heat, and the convergency of its particles, even at that distance, will soon be indicated by an increase of temperature in the thermometer. If the iron be made red hot, it will immediately set fire to a piece of phosphorus, placed in the focal point of the opposite reflector.

This reflection and concentration of heat can only be explained by a reference to those laws which are known to produce similar effects on the rays of light.

When we observe the very similar effects which are produced by solar, culinary, and electrical fire, we are disposed to believe that it is the same principle under different combinations.

The elementary principle of fire in a latent state, it is probable, does not exist independently, any more than the elementary bodies, oxygen or hydrogen: The different combinations of these bodies present different appearances and various results; so may we suppose that the different characters under which heat exists, depend more upon the particular bases with which it combines, than any real difference in the matter. Thus, caloric united with light, forms solar heat; with terrestrial bodies, culinary fire, and with an intermediate base formed between light and the grosser particles of matter, electric fluid.

The continued influence of solar heat ripens vegetable productions; yet fruits are produced at all seasons by means of culinary heat, or that heat which results from the decomposition of common inflammable bodies; and it is found that plants which are gently electrified daily, vegetate with encreased strength and rapidity.

Metals are melted, or the attraction of cohesion by which they exist in a solid form, is equally overcome by solar, culinary, or electrical heat. Whenever a body changes its capacity for caloric, its electrical quantities change, and likewise its conducting power of electricity. All bodies contain electricity, but in different quantities; and all bodies contain caloric, but have different capacities for it.

Mr. Davy has discovered that chemical affinity, or the principle by which the particles of different bodies combine, is produced by the different electrical states of those bodies. We find all chemical changes accompanied by an alteration of temperature and a change of electrical capacity in the compound mass; may not, therefore, the chemical combination be produced by the union of the electric bases, rendering caloric rather the agent than principle of chemical affinity?

Such is the chemical or electrical disposition of sulphuric acid for water, that if equal quantities of strong sulphuric acid and water be mixed together at a temperature of 60 degrees, the compound will be instantly raised to 220, or 8 degrees above the boiling point of water.

From the quantity of heat evolved, the particles are brought into more immediate connection, and the volume of the mass is diminished; that is, if equal quantities of the two fluids were mixed together, the bulk of the compound would not be equal to the bulk of the masses separately taken. This effect shews a tendency to solidity, in proportion to the quantity of heat evolved from the two fluids.

Alcohol, or spirit of wine, as it is generally called, has great affinity for water.

If strong Rum be poured into an equal quantity of water, at a temperature of 60 degrees, it will instantly produce an increase of 8 or 10 degrees of heat.

To many who are in the habit of diminishing the strength of ardent spirit for sale, this decrease of bulk on the addition of water may seem a little paradoxical.

Suppose a person takes 90 gallons of rum, one in three over-proof; that is, three gallons of the spirit take one of water to reduce it to proof, or that standard by which the impost is paid: to the 90 gallons he puts in one third, or 30 gallons of water; it might be presumed that the measure of the whole would be 120 gallons; but the dealer is well aware that he shall only obtain about 117 gallons, 3 gallons having disappeared by the union. The chemical affinity by which these two bodies are combined, sets free a considerable quantity of caloric, and the attraction of cohesion brings the particles of the fluids nearer together, consequently the bulk is reduced.

A diminution of temperature is likewise produced by chemical combination.

If sulphate of soda be added to muriatic acid at a temperature of 60 degrees, it will be immediately reduced to 28 degrees, or 4 degrees below the freezing point of water. This arises out of the liquifaction of the salt, which takes up the caloric that previously existed in the acid, and the temperature of the whole becomes diminished according to the quantity of caloric absorbed.

It is on this principle that all refrigerating mixtures are formed, some of which are potent enough to freeze quicksilver and render it solid.

If a portion of mercury be enclosed in a thin glass tube and placed in a mixture of light fresh fallen snow and muriate of lime, with proper attention in the process to prevent the accession of heat from surrounding bodies, the mercury will soon be converted into a fixed and solid mass, capable of being beaten out by a hammer. Allen and Pepys froze 56lbs. in this manner.

The diminution of temperature required to freeze quicksilver, or mercury, is 72 degrees below the freezing point of water, or 40 degrees below zero, the lowest point of Fahrenheit's scale. At some seasons the cold in Kamtschatka is said to be sufficient to freeze quicksilver, by merely exposing it to the atmosphere.

In the preceding experiments, the extraordinary degree of cold is produced by the liquifaction of the two solids, the salt and the snow. To obtain this liquified state there must be a supply of caloric, and the mercury which is in contact with the mixture is deprived of it to such an extent as to suffer the attraction of cohesion to fix to the mass.

It is a general axiom, that without motion there is no sensation. This will particularly apply in accounting for our sensations of heat and cold. For instance, if the hand be brought into contact with water of greater temperature than the body, the particles of caloric in the water, obeying the general disposition of nature to obtain an equilibrium, enter the hand, and the sensation of heat is, under common circumstances, according to the quantity of caloric united with the body.

If the water possesses less temperature than the body, the caloric proceeds from the hand to the water, and we have the sensation of coldness according to the quantity transmitted.

In all cases as soon as the motion of the particles of caloric ceases, or when the equilibrium obtains, the sensation ceases; we feel an existing body, but have no perception of heat or cold.

These sensations are frequently relative: we often hear it stated, by the uninformed, that the water of a well, or spring water, is warmer in winter than in summer. In summer our bodies have a higher temperature than in winter, therefore the difference is greater between the body and the fluid, and the degree of sensation is proportional. The same property is frequently attributed to Cellars, or places under ground, where the heat remains nearly the same at all times of the year, from the want of free communication with the different temperatures of the exterior air.

On entering such a cellar, in summer, we pass from a warmer atmosphere to a colder one, therefore we experience a sensation of coldness; but in winter we pass from a colder atmosphere to a warmer one, consequently we experience the sensation of heat.

Bodies vary in their conducting capacities; some conduct heat with much more facility than others. If a short rod of iron and glass be placed with their ends in a fire, the opposite end of the iron will soon become hot, whilst the opposite end of the glass rod will scarcely be warmed. Or, if we take hold of a piece of wood, and a piece of iron of the same temperature, the wood will seem warmer than the metal, because the wood is not so good a conductor, or does not convey the same quantity of caloric in the same time.

The different degrees of warmth which we experience from different kinds of cloathing, arise from this circumstance: We feel more warmth from Woollen or Fur, than from Linen or Silk, although the actual temperature of each be the same. Our sensation of warmth does not arise from any heat contained in the cloathing, but from the different conducting capacities in carrying it off from the body. When the atmosphere has less temperature than the animal body, the heat passes off, which is more or less obstructed by the different kinds of cloathing that surround the body. Woollen and Fur conduct heat with much less facility than Silk or Linen; therefore we experience more warmth from the former than from the latter, inasmuch as less heat is carried off in the same time.

Water is a better conductor of heat than air. In a thaw it frequently feels colder than during a frost, although the thermometer shews an increase of temperature. The vapourous state of the atmosphere which generally accompanies a thaw, carries off the heat from the body with much more facility than the dry air of frosty weather.

Bodies have different capacities for heat; or equal quantities of heat added to different bodies, at the same temperature, produce in them different temperatures. But if a certain quantity of heat be added to the same body, whatever its temperature may be, the augmentation will be always equal. Or if different temperatures be united, a mean temperature will be produced. If water at 60 degrees be mixed with water at 80 degrees, the heat will be 70 degrees; but if water at 60 degrees be added to ice at 32 degrees, the water will be reduced to 32 degrees, from the capacity of the liquified ice for caloric.

Quicksilver having less capacity for heat than water, if equal quantities of heat be added to the two bodies, the temperature of the quicksilver will be more increased than that of the water. From the different capacities of metals, under the same temperature, Zinc expands three times as much, and Brass twice as much as iron.

Although it is stated as a general position, that bodies increase in bulk under an augmentation of heat, yet there is a remarkable exception in water, at a particular temperature.

During the time that heat is employed in raising water from 32 degrees to 40 degrees, the bulk contracts, or *continues diminishing:* From 40 degrees to 212 degrees, the boiling point, it increases regularly. In cooling also, its bulk diminishes until the temperature falls to 40 degrees, after which it continues to expand until it is converted into ice.

Oxygen.

THIS body is placed next to caloric, not only from its undisputed pretension to rank as an elementary substance, but likewise on account of its great importance in the animal, vegetable, and mineral kingdoms, in which it exists in different states of combination, and forms a considerable portion of these bodies.

The most simple state of combination in which we can examine this elementary substance, is in the character of gas, where it is merely united with heat, and forms *Oxygen Gas.* This constitutes an important part of our atmosphere, and is the only source of combustion and support of animal life.

According to Lavoisier, in 100 parts of pure atmospherical air, there are 28 parts of oxygen gas, 70 of an elementary gas, called Nitrogen, and 2 parts of a compound air, called carbonic acid gas. Mr. Davy does not admit the portion of oxygen to be quite so great.

These bodies are not to be considered as constituting the whole of the air which we breathe: the atmosphere is a very heterogeneous mixture, and is the receptacle of many bodies that lose the cohesion of their parts by exhalation, fermentation, putrefaction, and many other processes of nature: a considerable portion of water, in a vapourous state, is likewise diffused in the atmosphere.

Oxygen gas is the only part of atmospherical air which is decomposed by combustion and respiration.

If a candle be put under a glass vessel and placed on a flat surface, air-tight, the flame will soon diminish until it is totally extinguished, and the glass will be found pressed down by the superincumbent atmosphere, in proportion to the quantity of air decomposed in the vessel by combustion.

This principle is better explained by the following experiment: Place a tall jar over a brass plate, having a tube and stop-cock connected with its underside. In the middle of this plate fix an upright stem, about a foot long, to support three pieces of lighted taper, one at the top, another in the middle, and the third at the bottom of the stem, near the plate. Soon after these tapers are excluded from a supply of atmospherical air, the uppermost will be extinguished, then the second; but the third, or lowermost, will burn for some time afterwards. If a jet be fixed in the center of the brass plate, on placing the lower extremity of the tube in water and turning the stop-cock, the pressure of the atmosphere will drive the water through the jet with considerable velocity, until the resistance of the interior air becomes equal to the pressure of the exterior. The water which has entered the jar, shews that a quantity of air has been decomposed by combustion, and the duration of the flame of the lowermost taper, demonstrates that the oxygen gas, from its superior gravity, remains longest at the bottom of the jar.

In cases of fire, this experiment points out the advantage of entering a room in a crawling position, so that the mouth and nostrils may be as near the floor as possible, where the greatest and longest supply of oxygen gas will be obtained. Most fires taking place in a room may be readily extinguished by merely shutting the doors and windows, and preventing any access of air from the chimney; this deprives the flame of a supply of oxygen, after it has consumed that which was in the room, and combustion ceases.

A candle requires about as much oxygen as is contained in a gallon of atmospherical air, to support its combustion a minute: It is reckoned that a middle-sized person would require about the same quantity for the same time.

Combustion, or inflammation, arises from a diminution in the capacity of the body for caloric. During the decomposition of oxygen gas by combustion, the oxygen loses its combination with caloric, and the heat produced by the inflammation is the caloric in a free state, which was previously united with the oxygen, and formed oxygen gas.

The great importance of this gas in supporting combustion, is interestingly shewn by the following experiment: Take three small jars, fill one with oxygen gas, the other with nitrogen gas, (that breathed from the lungs will be sufficient,) and let the third remain filled with atmospherical air; if a burning taper be put in the last, the oxygen contained in the atmosphere, will be sufficient to support a moderate combustion; if the taper be removed into that which contains the nitrogen gas, it will be extinguished instantly; but on introducing it into the jar that contains the oxygen gas, whilst the smallest spark remains, the flame will be immediately rekindled and burn with the greatest brilliancy.

Those who wish to make a few experiments with oxygen gas, for amusement, may obtain a sufficient quantity by the following method: Put about two ounces of manganese into a Florence flask, or bottle, with as much sulphuric acid as will form it into a paste; then place it over a spirit lamp, having fixed a piece of tube, either of metal or glass, bent in the form of an S, with one end communicating with the interior of the bottle through the cork: As soon as the gas begins to be evolved, place the open end of the tube under a jar filled with, and inverted in a vessel of water; the oxygen gas will soon displace the water and be collected for use in the jar.

It is a more commodious way to fill an iron retort with manganese alone, and place it in the fire. To the neck of the retort a metallic tube is fixed, which passes into a proper vessel filled with water, called a Gazometer, or Air-holder; from this it is easily obtained as occasion requires.

The importance of oxygen gas in supporting animal life, becomes a peculiarly interesting part of this subject.

If an animal be placed in a limited quantity of atmospherical air, a portion of the air will be consumed, and the animal will then die unless it receive an additional supply.

The process of respiration is divided into two parts, called inspiration and expiration: Inspiration brings the atmospherical air into the lungs, and expiration forces it out again.

During the time that the air is contained in the air vessels of the lungs, the blood is projected by the action of the heart through bloodvessels which are placed contiguous to the air-vessels. The blood, on entering the lungs, has a dark or blackish appearance, but when it is returned back to the heart, having passed through the bloodvessels which are spread on the air cells, it is found to have obtained a florid red colour. From the heart, this florid blood is sent out again by the arteries to the extremities of the animal body, and is returned back to the heart through the veins, deprived of its bright red, and changed to the blackish colour before described; it is then again sent through the lungs; and thus it continues to circulate as long as life exists.

Dr. Priestly suspected that this florid appearance which the blood obtained in its circulation, arose from the absorption of oxygen in the lungs, or what he called dephlogisticated air. He filled a bladder with venous or dark coloured blood, and placed it in a quantity of oxygen gas, having previously determined the weight of the gas, and the weight of the blood in the bladder. It was soon evident that that portion of the blood which was in contact with the bladder, obtained, exclusively, a florid appearance; and on examining the oxygen gas, Dr. Priestly found it had sensibly diminished in bulk and weight, and that the blood in the bladder had increased its weight as much as the air had lost it.

This absorption of oxygen seems to prove that a similar absorption takes place in the lungs, and that the oxygen contained in atmospherical air, pass into the blood through the membrane that forms the vessels which contain the air and the coats of the blood-vessels, and produces the florid appearance that the arterial blood possesses.

By what means this decomposition is effected, how this florid appearance is produced, and of what importance is the oxygen in supporting vitality, are questions that are not readily answered. It is generally supposed that this affinity is produced from the ferruginous particles which are contained in the blood, and that the union of these particles with oxygen gives the blood its florid appearance. That the oxygen is distributed through the system during the circulation, may be inferred from the difference of colour between the arterial and venous blood.

Messrs. Allen and Pepys have recently made accurate experiments on the air breathed from the lungs, and conclude that the nitrogen gas is returned unchanged either in quantity or quality. The small quantity of carbonic acid gas contained in the atmosphere which enters the lungs, is increased 10 per cent in the air that is returned from them, and a small portion of oxygen is found in an unchanged state.

The animal body possesses, during life, a greater degree of heat than the atmosphere or medium in which it exists; but after death it is soon reduced to a common temperature.

This superior heat is undoubtedly a consequence of animal life, and is generally supposed to be produced by the caloric which becomes free from the decomposition of oxygen gas in the lungs; the oxygen being deprived of its previous combination by the chemical influence of the blood, or some body contained in it. The caloric which is thus disengaged diffuses itself through the animal system; aids the various secretions, and evaporates those excreted fluids which are thrown from the surface of the body through innumerable pores. These important operations carry off the liberated caloric, and prevent that accumulation of heat which otherwise would not fail to destroy animal life. When spasmodic contractions of the pores stop the excretions, we find that inflammation or fever immediately takes place.

When the vital operation of oxygen gas in the lungs was completely substantiated, some began to imagine that we had discovered the long-looked-for elixer vitæ of the Alchemists;

that nature might be perpetually renovated and life prolonged, by inspiring this gas in its pure state, when the system was falling into decay. This golden dream was but of short duration, for the experimenter soon found to his cost, that so far from improving his health, the gas added to his disease, by causing too great irritability in the system, which excited fever, and produced convulsions that would speedily have terminated his existence.

Our reason tells us that man is expressly formed for the atmosphere which he breathes, and to force upon him another, is to argue a want of fitness in the first. Indeed so guarded are the functions of the lungs against admitting too much oxygen, even from the atmosphere, that the increased quantity of carbonic acid gas which is expelled from the lungs is supposed to be formed of redundant oxygen united with carbonaceous matter provided by nature in the system to prevent the blood from being overcharged.

Oxides.

THESE bodies may be either fluid or solid, and are formed by the union of oxygen with some other substance.

Water may be ranked under this description: It is formed of oxygen and an elementary body, called Hydrogen.

Water is decomposed by passing through a heated gun-barrel: By this process the oxygen of the water is so strongly attracted by the red-hot iron, that it will leave its combination with the hydrogen and unite with the gun barrel, forming an oxide of iron; the hydrogen being set free, escapes plentifully in the character of gas.

If oxygen gas be mixed with hydrogen gas and inclosed in a strong vessel, on igniting them with a taper, or the electric spark, an explosion takes place, and pure water is produced. Thus water is analytically and synthetically proved to be formed by the chemical union of these two bodies.

From the recent improvements in chemistry, requent changes are taking place in chemical pinions; but if there be a body in nature, the composition of which has been well ascertained, t surely must be that of water. Composition and decomposition agree in shewing its elementary principles so satisfactorily, that there does not seem to be two opinions upon this subject.

Oxygen forms a portion of Alcohol, Æther, and some other fluids that have no acidity.

When oxygen is united with metals, the body is called an oxide. Metallic ores are generally found in this state of combination; the operation of fluxing drives off the oxygen, and the metal is obtained in its pure state.

Manganese is found in the state of a metallic oxide, which has great affinity for oxygen, although a portion of it is so loosely held that it readily unites with caloric and forms oxygen gas. It is from the oxide of manganese that oxygen gas is usually obtained for chemical experiments, by subjecting it in an iron retort to the influence of heat.

The great affinity that exists between oxygen and iron, is the cause of the red rust which that metal so readily obtains: for rust is an oxide of iron produced by the decomposition of water or vapour.

If a piece of red hot iron be immersed in water the surface obtains a scaly appearance, which is an oxide of iron. In this experiment the water is decomposed, the oxygen unites with the iron, and the hydrogen is set free, which is easily known by its smell.

Oxygen has different degrees of affinity for different metals. There are some with which it very reluctantly combines; Gold, Silver, and Platina are of this description, consequently these metals are convenient for chemical vessels that are to be exposed to heat and acids. Copper does not readily combine with oxygen. The more oxydable metals are Zinc, Tin, and Lead.

From the great capacity of Zinc for oxygen, it is used with copper in forming the Voltaic or Galvanic trough, as it is generally called.

Metals lose their capacity for electricity by oxydation. If a piece of zinc and copper be brought into contact and have their surfaces wetted with a weak acid, the oxygen of the acid will readily unite with the zinc, without materially affecting the copper. During this combination the latent electricity of the zinc becomes active or positive, and is induced towards the unoxydised body, the copper, which is relatively negative.

The intensity or force of the electricity is according to the quantity of metallic surface acted upon; therefore, to produce powerful electrical effects, a number of compounded plates are employed, which form the Voltaic Battery, an apparatus which has effected more for the sciences of electricity and chemistry than any other invention that has ever been introduced.

The oxydation of metals by inflammation in oxygen gas, produces a number of beautiful experiments. One of the most striking in chemistry, is the deflagration of iron wire.

Twist a piece of ordinary iron wire into a spiral form, then wrap a piece of greasy tow about one end of it, and set it on fire; when it is nearly burnt out, introduce the wire into a jar of oxygen gas, and the heated end will instantly begin to burn with the greatest splendour, throwing out beautiful scintillations of red hot iron, until the whole of the oxygen gas is decomposed. Particles of the iron oxygenized, and sometimes vitrified from the extense heat, will be found at the bottom of the vessel of a spherical form. If the wire be carefully weighed before the experiment, and the oxide afterwards, the difference or increase of weight, will be exactly equal to the weight of the oxygen gas consumed in the experiment. The iron loses its metallic lustre and ferrugenous qualities by oxydation, and is no longer sensible to the magnet; but by exposing the oxide to fire, the oxygen will again unite with the caloric, and the iron will be restored to its true metallic state.

This experiment, in common with all others, shews that matter can neither be created nor annihilated. Every change which appears to destroy the parts of a body, only dissolves the combination of its parts, and induces them to take up fresh forms, either in the solid, fluid, or gasseous state; for if the results of any chemical experiment be carefully collected, we still find the same weight or the same quantity of gravitating matter. Our reason tells us it cannot be otherwise. If matter could be annihilated, the laws of nature would be inconstant, and the harmony of the universe would be destroyed; for the force of gravity would perpetually change, and the planetary bodies would no longer obey their central influence.

Here the rational mind finds abundant subject for reflection. Can matter create itself, or prescribe laws for its own government? A machine has its maker; so has our system its creator; and every part equally manifests infinite power, intelligence, and design.

The compound materials of which our bodies are formed, strictly obey their respective affinities whilst life exists; but death no sooner separates the spiritual from the corporeal part, than the latter commences its changes, and by established principles of nature, soon resolves itself into its elementary particles and mixes with its kindred earth.

The elements of matter in vegetable bodies are equally susceptible of change, and produce that variety of combination so necessary and essential to the comforts and convenience of man, yet without altering those fundamental principles that govern nature in the aggregate.

It has already been stated that oxygen gas is decomposed, that the oxygen takes a new combination in the process of respiration, and that this gas is equally essential to combustion. It is calculated that even a common candle decomposes as much oxygen, whilst burning, as a man does by respiration in the same time. Now considering the prodigious demand that is perpetually made upon the atmosphere, one would suppose that in process of time, this fluid medium would become exhausted; but, on the contrary, the oxygen of the atmosphere is found to be every where the same in quantity: Even in the closest parts of London and Paris, the circulating air sustains no sensible diminution; the unhealthiness of such situations is attributable to the exhalation and mixture of putrid effluvia, and not to any change that takes place in the constituent parts of the atmosphere itself.

We are then naturally led to ask from what sources the oxygen gas is supplied which is so abundantly consumed? The means are fully adequate to the effect; the whole vegetable creation is perpetually compensating for the wasted store. What inimitable contrivance!—Even this issolated example of Divine Wisdom, when viewed with the eye of reason, must be sufficient to convince the greatest sceptic, that there is an Almighty Being whose wisdom and goodness are only equalled by his power.

Acids.

OXYGEN is the principle of acidity, and united with certain substances, called acidifiable bases, produces acids, which have generally, but not without exception, a sour taste. Acids turn vegetable blues to a red colour, and readily unite with alkalis, forming salts.

This acidifying principle may exist in three states of combination with its bases. Firstly, when the saturation of the body with oxygen is not complete; secondly, when it is completed; and thirdly, when the body contains more oxygen than is necessary for its saturation. According to the present chemical nomenclature, in the first case the name of the base terminates in *ous*, as sulphureous acid. The second in *ic*, as nitric acid, and the third is called oxygenized, as oxygenized muriatic acid.

Acids are plentifully produced by the chemical processes of nature, and in some of them the oxygenous principle has such affinity for its base, that they have never been separated. Of this description are the Muriatic, Boracic, and Fluoric acids.

Although various other bodies which have long been considered as purely elementary have been detected to be compounds by the operation of the Voltaic Battery, in the able hands of Professor Davy; yet the decomposition of the above mentioned acids has never been satisfactorily effected: But from the rapid progress that is almost daily made in chemical science, it seems very probable that ere long their component parts will be perfectly analysed and understood; in the mean time we may be permitted to judge from analogy, and conclude, that oxygen is the acidifying principle, which, as in all other instances, is united with these different bases.

Acids differ from Oxides in their quantity of oxygen. An inferior quantity produces an oxide; a superior quantity approaching saturation, an acid. Metallic bodies have different capacities for oxygen; some will only receive a slight degree of oxidizement; others are readily converted into oxides, which have no acidity; and some metals are capable of uniting with oxygen to such extent as to be convertible into acids.

Hydrogen.

THIS body ranks with oxygen as an undisputed element of nature, and of such importance, that it seems highly probable, from recent discoveries, that ere long all matter will be resolvable into these two principles.

The Ancients believed Fire, Air, Earth, and Water to be the four elements of which all other bodies were constituted. For some years past we have been well assured that three out of the four are compounds; and that the fourth, Fire, is now generally supposed to be divisible into light and heat, two distinct bodies.

There seems to be considerable doubt at the present moment, respecting the number of elementary bodies. Modern chemists have considered Caloric, Oxygen, Hydrogen, Nitrogen, Carbon, Sulphur, Phosphorus, five alkalis, seven earths, and twenty-seven metals, to be elements; but Mr. Davy shews that the alkalis are compound bodies, formed of oxygen and a metallic base; that the earths supposed to have been simple, are similarly compounded, and that Sulphur, Carbon, and Phosphorus, cannot be ranked as pure elements. Oxygen and an inflammable base appear to be universal principles, intimately united by opposite states of electricity; and as chemical composition arises solely out of electrical energies, it would not seem very absurd to suppose that there are but two elementary principles in nature, one existing in a positive, the other in a negative state of electricity.

Hydrogen in itself is incapable of inflammability; this property is derived from its union with oxygen, which is the only source of combustion. If a lighted taper be plunged into a jar of hydrogen gas, it is instantly extinguished; but the hydrogen will burn slowly at the surface, where it obtains a portion of oxygen from the atmosphere.

Hydrogen, or the elementary principle which forms hydrogen gas when united with a sufficient quantity of caloric, is most abundantly distributed throughout the animal, vegetable, and mineral kingdoms, and forms the inflammable part of those bodies into which it enters. This gas, combined with others, is frequently spontaneously produced in and near coal mines. Exploding in the mine it has often been productive of fatal consequences; but it may be collected from fissures in the neighbourhood with perfect safety, and used for many amusing experiments.

An impure hydrogen gas is likewise to be obtained by thrusting a stick into a ditch of stagnant water: When the stick is withdrawn, bubbles of air will ascend which may be collected in an inverted jar of water. Hydrogen gas is plentifully evolved from animal and vegetable substances during the putrid fermentation or decomposition of the body.

When hydrogen gas is perfectly pure, it is without taste or smell; but it is generally obtained with certain impurities that proceed from the bodies from which it is liberated, and these communicate a very disagreeable effluvia. Even in its purest state it is incapable of supporting animal or vegetable life.

The usual mode of obtaining this gas for common experiments, is by pouring dilute sulphuric acid upon iron shavings, or filings, in a glass bottle, which produces a brisk effervescence, when the gas is plentifully given out. A large phial, or a common glass bottle, with a piece of bent tube fixed in the mouth, by a cork, is quite sufficient for general purposes; and iron nails may be used instead of iron filings or shavings: the purest hydrogen is obtained from zinc.

In this process water is decomposed. Water being formed of oxygen and hydrogen, the oxygen is taken up by the metal and forms an oxyde of iron, and the hydrogen is set free in the gasseous state, which being permanent over water, is easily collected and retained in glass vessels previously filled with this fluid.

Hydrogen gas was discovered by Mr. Cavendish. When pure it is about twelve times lighter than atmospherical air, and a hundred cubical inches of this gas do not weigh more than three grains: An equal quantity of atmospherical air weighs about thirty-four grains.

From the peculiar lightness of this gas it is used for inflating balloons.

When the weight of a balloon with all its appendages, is less than the weight of the atmospherical air displaced by it, it will ascend: but as the atmosphere diminishes in density in proportion to the distance from the surface of the earth, the balloon would only rise to a limited height, if means were not adopted to diminish its weight at different altitudes. This is effected by ascending with bags of sand in the car which is attached to the balloon; these being occasionally discharged, it rises higher and higher according to the will of the Æronaut. When he wishes to descend, the hydrogen gas is suffered to escape through a valve in the top of the machine, which diminishes its bulk, and renders it heavier than the air that is displaced by it, consequently it descends with a velocity according to the difference of gravity between the balloon and the displaced air.

This principle of balloons is amusingly illustrated, by forming hydrogen air bubbles with a solution of soap, which ascend with considerable rapidity: These may be easily produced by fixing a short pipe to a bladder of hydrogen gas, tying the bladder at the end of the pipe when the gas is not wanted for the experiment.

Artificial fireworks are pleasingly made by the inflammation of hydrogen gas; but this experiment requires a proper apparatus, which may be procured of those that sell chemical instruments. The ignited air may be varied in colour by introducing different gasses through separate branches into the principal tube.

Hydrogen unites with oxygen, nitrogen, carbon, sulphur, and phosphorus: The results of these combinations produce a great variety of interesting experiments, which will be noticed in their respective places.

If equal quantities of hydrogen gas and atmospherical air be mixed together and ignited by a lighted taper, or the electrical spark, detonation will take place; but if pure oxygen gas be mixed with the hydrogen in the proportion of three parts of the former to one of the latter, the detonation will be much louder and sharper, the whole of the gas will disappear, and water be produced. The weight of the water formed by this union is exactly equal to the weight of the two gasses employed.

To perform the last experiment accurately, an expensive apparatus is required; it will be sufficient, for the purpose of general explanation, to mix the oxygen and hydrogen in a bladder, and form soap bubbles with the compound; these will not only produce a sharp and loud detonation when set on fire, but the different velocities of the bubbles according to the quantity of oxygen introduced into the bladder, will shew the different gravities of the gas.

Atmospherical air compressed by a piston in a brass cylinder evolves a sufficient quantity of caloric to set fire to inflammable bodies: If oxygen and hydrogen gas be mixed and compressed in a similar situation, they will ignite and explode.

Water is decomposed by passing a considerable number of electrical discharges from a large battery through a glass tube filled with it; this produces a gas composed of oxygen and hydrogen. But this experiment is much more beautifully and conveniently effected by means of the voltaic apparatus: If two wine glasses filled with water, be severally connected by means of wire with the positive and negative ends of the voltaic trough, bubbles of air will be instantly given out from the extremities of each wire: that which proceeds from the positive wire will be found to be oxygen gas, and that from the negative, hydrogen. These gasses may be collected and again converted into water by the electric spark of the apparatus.

gas. This air was [illegible]
oxygen of the [illegible]
lungs, and that [illegible], or [illegible]
combustion, or [illegible]

The Cavendish [illegible]
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Water does not take up either oxygen, hydrogen, or nitrogen gas separately; but if the two latter be combined, it readily unites with them.

Oxygen and hydrogen gas acted upon by the blow pipe, produce an intense heat. For this purpose the gasses are to be separately included in two bladders, with a stop-cock and fine pipe attached to each; when the hydrogen gas is ignited at the end of the tube, the oxygen is to be directed towards it and forced into the flame, which will produce sufficient heat to flux metals in a few seconds. The gasses must not be mixed in the same bladder, otherwise they will instantly detonate when ignited. The word detonate is used because this effect cannot properly be called an explosion, as that term implies an expansion or divergency; but in this case the effect arises from the collapsing of the atmosphere by the sudden contraction or reduction of these gasses into water. In the explosion of gunpowder the effect is produced by the expansion of the air or vapour which is generated.

Nitrogen.

NITROGEN gas forms nearly three fourths of our atmosphere; but is incapable of supporting either combustion or animal life. It is not absorbable by water, and its weight in proportion to atmospherical air, is as 905 to 1000. Nitrogen gas may be obtained by the decomposition of the atmosphere, or from animal substances, which contain an abundant quantity of nitrogen.

If a paste be formed of sulphur and iron filings, moistened with water, when this mass is placed in a vessel containing atmospherical air, for a day or two, the oxygen becomes absorbed; and pure nitrogen gas remains.

The air breathed from the lungs is nitrogen, but impure from the mixture of carbonic acid gas: this air may be employed to shew that the oxygen of the atmosphere is absorbed in the lungs, and that the expired gas will not support combustion, or animal life.

Mr. Cavendish discovered that *Nitric Acid* was formed by the union of nitrogen and oxygen: If a number of electric shocks be passed through a mixture of oxygen and nitrogen gas, nitrous acid is produced. Nitric acid is that state in which the nitrogen exists in complete oxygenation; then the fluid is colourless, and is commonly called Aquafortis. When the basis of the acid has not its full portion of oxygen, it is called nitrous acid, and has an orange or red colour. The vapours which fly off from this sub-oxide have likewise a reddish appearance, and attract rapidly the oxygen of the atmosphere, forming nitrous gas. When the vapours are fully oxydated and condensed, they form nitric acid.

From the great affinity of nitrous gas for oxygen, it is employed to shew the quantity of oxygen contained in atmospherical air; consequently, the fitness of this air for animal respiration.

When nitrous gas is mixed with oxygen gas, in proper proportions, heat is evolved; and if the gasses be pure, they will totally disappear. If nitrogen gas be added to nitrous gas, no chemical union takes place, but the volume is increased according to their respective quantities: therefore, if atmospherical air be employed, which is composed of oxygen and nitrogen, the volume will be increased by the quantity of nitrogen, and the whole bulk diminished by the absorption of the oxygen. This mode of investigating the atmosphere was first adopted by Dr. Priestly, and has been lately revived by Dalton.

The gas, called *Nitrous Oxide*, is a compound of oxygen and nitrogen, but contains a less quantity of oxygen than nitrous gas. If nitrous gas be exposed to iron filings, the metal becomes oxydated by a portion of the oxygen obtained from the nitrous gas, and the remaining air is the nitrous oxide.

The usual mode of obtaining nitrous oxide is by the decomposition of a salt, called nitrate of ammonia, formed by nitric acid and the compound alkali ammonia. When some of this salt is exposed in a retort to the heat of a spirit lamp, it becomes fluid, and is soon afterwards converted into gas, which may be collected for use in an inverted vessel of water.

This gas has a very remarkable effect upon the nervous system, when it is received into the lungs.

If a large bladder or an oiled silk bag, containing about five or six quarts, be filled with this gas, after respiring it for about a minute, by means of a tube fixed in the neck of the bag, a great exhilaration of the spirits is produced; highly pleasurable sensations, great disposition to muscular exertion, and most frequently an irresistible propensity to laughter. This effect continues for about two minutes, after which the person perfectly recovers, without experiencing any subsequent depression of the nervous system, or muscular debility, which invariably follows the action of any other stimulus yet known.

This gas possesses a sweet taste and an agreeable smell; it has nothing prejudicial in its effects, although different persons are very differently affected by it. Some breathe this gas freely, without experiencing any other effect than that of a temporary stupor; and others become most violently excited by it. Much seems to depend on the natural character of the person who breathes it. If he be of lively imagination and active disposition, the effects will be correspondent: but if more grave, the operation will not be so violent; and in some instances where the person has been of very phlegmatic character, it has not produced any effects whatever.

The nitrous oxide is composed of oxygen and nitrogen, the same elements as the atmosphere, and, according to Mr. Davy's analysis, 100 parts of this gas contain 37 oxygen and 63 nitrogen: the atmosphere, according to the same authority, being composed of 22 oxygen and 78 nitrogen.

From the quantity of oxygen which the nitrous oxide contains, it detonates loudly with hydrogen, and supports a rapid combustion of inflammable bodies. Yet if an animal be confined wholly in this gas, it will soon die: the lungs however may be inflated for some time without the least danger; for during the short period of breathing the nitrous oxide, it becomes diluted by the atmospherical air which previously occupies the lungs.

Carbon.

ALTHOUGH Charcoal and the Diamond are bodies very unlike each other in their external appearances, yet on analysis their results are the same. A diamond subjected to a certain degree of heat becomes volatilized, and is converted into carbonic acid gas: Charcoal burnt in oxygen gas produces the same result. Guyton considers common charcoal to be an oxide of carbon. Plumbago or black lead is an oxide of carbon in an inferior degree of oxygenation. Carbonic acid is the result of the complete oxygenation of charcoal.

Charcoal is brittle, black, and sonorous; it is obtained from the animal, vegetable, and mineral kingdom. Charcoal has the singular property of absorbing gasses without undergoing in itself any change. It has likewise an antiseptic effect; so that meat which is a little tainted may be restored to its former sweetness, by rubbing it daily with charcoal, or burying it in charcoal powdered. Water at sea is kept much sweeter by charring or burning the inner surface of the cask.

When charcoal is burnt in atmospherical air, or oxygen gas, it produces a gas, one and a half times heavier than the air of the atmosphere, called CARBONIC ACID GAS; this is a compound of oxygen and carbon, rendered gasseous by caloric. It will not support combustion or animal life. For the analysis of this gas we are indebted to Dr. Black.

By the vinous fermentation this gas is most abundantly produced, and it gives that brisk and pleasant taste which is so agreeable in malt liquors, cyder, perry, &c. During this fermentation in open vessels, the carbonic acid gas generated, frequently falls over the edge so plentifully as to extinguish a candle, or any other ignited body that is brought near the outside of the vessel.

When the liquor is drawn off from a large vat, the gas pressed down by the atmosphere remains at the bottom of the vessel, and has often been fatal to persons inadvertently entering the vessel to clean it out before proper means have been taken to get rid of this noxious deposit.

This gas is frequently found in abundant quantity in caverns, wells, and cellars that have been shut up for some time. Persons should use great caution in descending into such places: If a lighted candle in a lanthorn be let down, and it continues to burn, any one may enter without danger; but if the candle be extinguished, about a peck of fresh lime must be pulverised and sifted down the well or dispersed through the cavern or cellar, which will absorb the carbonic acid gas, and render the air fit for respiration.

In a cavern near Naples, there is a constant exhalation of this gas, forming a stratum which rises to the height of about two feet; so that persons may enter the cavern and walk about without experiencing any inconvenience: but if a dog or any other quadruped that has its nose within two feet of the ground, be thrust into this place it instantly becomes convulsed, falls down senseless and would soon be deprived of its life, if the unfeeling wretch who exhibits this curious phenomenon did not drag it out into the open air, that it may be restored to undergo the same torture for the cruel entertainment of the next traveller.

Carbonic acid gas has great affinity for all calcareous earths, of which description are chalk, limestone, and marble: in these masses it plentifully exists, and the compound is called carbonate, or rather sub-carbonate of lime.

Stalactites, or the conical petrifactions which are found with their bases sticking to the roofs of caverns in many parts of England, are of this description, and are formed in the following manner: Rain falling upon limestone in the neighbourhood of these caverns, dissolves a certain portion of calcareous earth by chemical affinity: the saturated fluid enters the cavern by drops, and as each drop is produced, the carbonic acid gas which naturally exists in this cavity, combines with the lime in solution and forms a concrete mass of carbonate of lime. Another drop passes over this solid substance, and another mass is deposited: continued concretion in this manner forms a large substance, the base of which sticks to the roof by the attraction of cohesion, and the conical form is produced by the force of gravity.

If we take a vessel containing carbonic acid gas, and pour lime-water into it, in as divided a manner as possible, the carbonic acid will seize the lime as it descends, and the transparent lime-water will instantly become thick and of a milky whiteness: This precipitate is found to be carbonate of lime, or common chalk.

Chalk or marble afford a ready means of obtaining carbonic acid gas for the generality of chemical experiments.

Those who have not proper gas bottles may take a common green bottle, with a wide mouth, and fit the bent tube described in the process for obtaining oxygen gas, into a cork that will close up the mouth of the bottle. This being prepared, put in some pounded chalk or marble, and then pour dilute sulphuric acid upon it. As soon as the cork is placed in the neck of the bottle, the carbonic acid gas will pass through the bent tube most abundantly, and may easily be collected by introducing the end of the tube into an inverted bottle of water placed in a tub of water.

The sulphuric acid having greater affinity for the calcareous earth than the carbonic acid, the latter is displaced in the preceding experiment, and is liberated in the gasseous state.

A pleasing experiment with this gas and which shews its remarkable weight, may be performed by placing a lighted taper in an empty jar, and pouring from another jar apparently empty, carbonic acid gas: the gas will actually descend into the lower jar and extinguish the taper. This experiment is rendered more complete by throwing a piece of lighted paper into the remaining gas; the smoke of which will be entangled in it, and shew the space it occupies in the glass, and its surface undulating with every motion, like water.

The formation of carbonic acid gas is illustrated by a beautiful experiment with a piece of charcoal bark. Ignite a small part of the bark with a blow pipe, and introduce it into a vessel of oxygen gas. The combustion being plentifully supplied with oxygen, the charcoal instantly begins to burn with great brillancy, and splendid scintillations are thrown off from the bark in every direction.

During this experiment the carbon, or charcoal, unites with the oxygen gas through the influence of caloric, and forms carbonic acid gas in the vessel which was previously filled by the oxygen gas.

There are many natural springs of water in which this gas plentifully exists, and united with different substances forms Seltzer water, Pyremont water, and many others: but these natural productions having been accurately analized, and their component parts being well understood, chemists produce artificial compounds, which are recommended by medical persons in preference to the natural fluids on account of the superior quantity of carbonic acid gas that is forced into them, and the exclusion of any injurious mineral.

Carburetted hydrogen gas is produced by uniting carbon with hydrogen, and may be obtained by distillation from wet wood or moistened charcoal.

The *coal-damp* in coal mines is carburetted hydrogen gas: this gas is frequently found issuing from cracks, or fissures in the earth, in the neighbourhood of coal mines. This was noticed by Dr. Clayton, more than a hundred and fifty years ago, and is mentioned by him in a letter to the Honourable Mr. Boyle, from Wigan, in Lancashire. Clayton finding that the gas was inflammable which issued from fissures near coal mines, suspected that this combustible principle resided in the coals; he accordingly took a portion of coal, put it into a close vessel leaving only a small aperture, and placed it over a brisk fire. Gas was soon given out at the aperture, which readily ignited and burnt for a considerable time. He also collected the gas in bladders, and occasionally inflamed it by pricking a hole in the bladder, for the amusement of his friends.

This account is taken from Boyle's manuscripts in the British Museum, and is probably the first circumstantial relation which we possess concerning carburetted hydrogen gas. This gas has been recently brought into considerable notice by a person who proposed to employ it in lighting streets, manufactories, public places, and private houses.

Whatever may be the pecuniary advantages from distilling coal for these general purposes, there are some inconveniences which greatly militate against the practice, and have induced many of those who have already adopted coal distillation to give it up.

To obtain a sufficient supply of carburetted hydrogen gas for lighting the rooms of a house, it must be previously produced and retained in a proper reservoir. From this general receptacle, it is conducted through the respective apartments by tubes; and if by accident the ignited gas should be extinguished, the tube still continuing to pour forth its store, the room is soon filled with a very disagreeable and noxious effluvium. It is true that much of the offensive smell may be taken away from the gas by passing it through lime-water; but the whole process is attended with much trouble, inconvenience and expence; and notwithstanding the value of tar and coke, the products of this operation, the generality of scientific persons seem to view it more as a matter of chemical amusement than as likely to be productive of public or private advantage.

Sulphur.

THIS substance, till very lately, was considered as one of the elementary bodies of nature, in other words, a body incapable of further decomposition; but Mr. Davy and M. Berthollet, jun. have ascertained that it is a compound: the latter found that it contained hydrogen, and Mr. Davy discovered that it likewise contained a small quantity of oxygen, with a large quantity of a basis that produces the acids of sulphur in combustion; and which, on account of its strong attraction for other bodies, is only with great difficulty separable from them.

Sulphur being a non-conductor of electricity, does not yield its elements to the attraction of the surfaces of the voltaic apparatus. So that when this is employed, more is effected by the operation of heat simply, than by electrical influence.

Sulphur is an inflammable body, and is found almost pure in the neighbourhood of volcanos. It is also found in great abundance in coal mines, and united with different metallic ores: in the latter combination the mass is called pyrites, and the principal part of the sulphur which is used in this country is obtained from copper and iron pyrites, either by sublimation during the process of roasting or smelting the ore, or by volatilization during the slow combustion of a pile of pyrites.

SULPHURIC ACID is produced by the union of a sufficient quantity of oxygen with sulphur, by combustion.

The sulphuric acid of commerce is generally obtained in the following manner: A quantity of sulphur, with about an eighth of its weight of salt petre, is placed in a large leaden chamber, with a portion of water covering the bottom. When the sulphur is set on fire, the combustion is supported by the oxygen contained in the salt petre, which produces an acid vapour; all acids having strong affinity for water, the vapour is rapidly absorbed by it: this compound is sulphuric acid and water. The next step of the process is to separate the acid from the water, which is readily effected by ebullition: for inasmuch as the sulphuric acid is nearly twice as heavy as the water, the latter is driven off in vapour before the former boils; thus leaving the concentrated acid at the bottom of the vessel.

This process is pleasingly illustrated by putting a small spoonful of ignited sulphur into a jar of oxygen gas: The sulphur, which will scarcely burn in atmospherical air, rapidly inflames as soon as it enters the gas, and burns with a beautiful blue light; the vessel is soon filled with sulphuric acid vapours, and a small quantity of water being left at the bottom of the jar, it readily absorbs them, and becomes acidulous, or forms sulphuric acid and water: if the aqueous part be driven off by evaporation, the concentrated acid will be obtained as in the preceding experiment. If a red rose be introduced into the acid vapours in the jar, it will be immediately blanched.

Sulphuric acid vapours are frequently employed in bleaching silk: for common purposes this may be effected by holding the silk over the fumes of burning matches in atmospherical air.

When sulphur is heated in hydrogen gas, it unites with the hydrogen and forms sulphuretted hydrogen gas, which has an exceedingly fœtid and disagreeable smell: this gas is inflammable. During its combustion a portion of oxygen unites with the hydrogen, and forms water; another portion of oxygen unites with the sulphur, and forms sulphuric acid.

This gas is produced naturally, and is plentifully given out from Harrowgate water; it is copiously absorbed by alkalis, and precipitates a number of metallic solutions. If characters be written with a solution of acetate, or sugar of lead, they become visible and almost black by exposing them to sulphuretted hydrogen gas. White paint which is formed from an acetate of lead is immediately blackened by exposure to this gas. Sulphuretted hydrogen in 100 parts, contains 29 hydrogen, and 71 sulphur.

Phosphorus.

THIS has also been ranked amongst the elementary bodies; but Mr. Davy's analytical researches prove that it possesses both oxygen and hydrogen. It is a solid inflammable substance, and is obtained chiefly from animal bones, in which it is combined with lime. It has very few useful properties, although it has lately been combined with soda, and recommended as a purging salt by Dr. Pearson, on account of its tastelessness. Phosphorus appears luminous in the dark, emits a feeble flame at an atmospherical temperature of 50 degrees, burns with a very vivid flame at 122 degrees, and passes into a gasseous state at 554 degrees.

Characters drawn on the wall or floor with a piece of stick phosphorus, are very bright in a darkened room, and remain visible a considerable length of time, but great care must be employed to keep the phosphorus from taking fire in the fingers, which will frequently happen in warm weather if it be not occasionally dipped in cold water.

A very brilliant experiment is produced by burning a piece of phosphorus in a jar of oxygen gas. When this is done in a darkened room, such an excess of light is emitted that the eye cannot bear its impulse, nor is it possible by any other chemical means to produce so luminous an effect. Phosphorus will likewise burn in nitrous oxide and oxygenated muriatic acid gas.

Phosphoric Acid is produced from the union of phosphorus with oxygen. This union is obtained by different modes: it may be obtained from bones or phosphate of lime; but the combination of phosphorus with oxygen in the preceding experiment is sufficient to convey a general idea of its formation.

Phosphorus acid which is in a state of oxygenation, inferior to that of phosphoric acid, is obtained by putting a piece of stick phosphorus in a glass funnel; in this situation it decomposes atmospherical air, and obtains a sufficient quantity of oxygen from it to become fluid, and form phosphorus acid.

Phosphorus unites with Hydrogen, and produces *phosphuretted hydrogen gas.* This is obtained by heating caustic alkali or quick lime with phosphorus and a small quantity of water. This gas is obtained with more facility by putting some zinc filings and a piece of phosphorus in a wine glass of water; on adding sulphuric acid the water is decomposed, the hydrogen of which unites with the phosphorus and forms phosphuretted hydrogen gas. This gas attracts oxygen so rapidly from the atmosphere, that it takes fire and explodes as soon as it reaches the surface of the water: the experiment is still more brilliant when the wine glass is placed in a jar of oxygen gas.

A very small portion of phosphorus is dissolved by putting it either in Oil or Æther for a few hours. The fluid may be rubbed on the hands or face with perfect safety, and renders them strikingly luminous in a darkened room.

If a small piece of phosphorus be put into a wine glass of water, with some oxygenated muriate of potash, on pouring in sulphuric acid, strong flashes of light will be produced at the bottom of the glass.

Small pieces of phosphuret of lime put into warm water give out phosphuretted hydrogen gas, which takes fire as soon as it meets the atmosphere.

The German fire boxes, or phosphoric match bottles, may be readily made by putting a piece of dry phosphorus in a clean phial, and placing it in a gentle heat, until the phosphorus melts and sticks to the sides of the bottle; then cork it up closely for use. If a common brimstone match be rubbed against the phosphorus in the bottle, it will immediately ignite.

Muriatic Acid.

THE acidulating part of this acid has such affinity for the muriate radical, or its base, that they have never been separated; although Mr. Davy states, that this subject has occupied much of his attention, and that he has operated upon muriatic acid in various ways without much success. Berthollet, however, thinks that this acid is formed principally of nitrogen, with a small quantity of oxygen and hydrogen.

Muriatic acid is obtained by distillation from a mixture of common salt (muriate of Soda) with half its weight of sulphuric acid.

Pure muriatic acid is quite colourless, and heavier than water in the proportion of 12 to 10: It has an unpleasant smell, and emits white fumes when it is exposed to the atmosphere.

MURIATIC ACID GAS is the purest state in which the acid exists; it has a pungent smell, and is sufficiently corrosive to injure the skin. This gas will not support flame or animal life. It may be obtained by pouring sulphuric acid on common salt; but it is so rapidly absorbed by water, that a trough of mercury is necessary to collect it, and keep it permanent.

When an additional quantity of oxygen is added to the muriatic acid, or gas, it forms *oxygenized muriatic acid*, or *gas*, which has a most suffocating smell, and destroys the generality of colours, particularly those that are produced from vegetables.

From this peculiar quality which was discovered by Scheele, a Swedish chemist, the gas and acid are now both used in the process of bleaching.

According to the old mode, the article to be bleached was steeped in a solution of alkali, and exposed to the sun and air for a considerable time, which ultimately removed the brown colour possessed by flax in its natural state, and left the cloth white. This process which generally occupied some weeks, according to the season of the year, or quantity of solar light, is now effected in as many hours, and when properly conducted, without any injury to the texture of the goods.

The oxygenized muriatic acid is sold ready prepared at the chemists' shops. To obtain it for private use, put a drachm of oxygenated muriate of potash into about half an ounce of muriatic acid; the gas will be immediately evolved; and if vegetable stains or printed cotton be introduced into the vessel of gas, the colouring part will be speedily removed without wetting or injuring the texture. If the muriatic acid be not tolerably strong, the vessel containing the acid and salt must be placed over a lamp, or candle, for two or three minutes, before the gas will be given out.

Care must be taken not to inhale the oxygenated muriatic acid gas, as it violently irritates the larynx, and almost instantly produces a catarrh. This gas is strongly recommended for destroying putrid effluvia in Hospitals, Barracks, Prisons, &c. The infected rooms are cleaned and then fumigated with the gas.

For the purposes of fumigation, this gas is cheaply produced by pouring dilute sulphuric acid on a mixture of manganese and common salt, exposing the whole to the heat of a lamp: the manganese supplies the oxygen, and the salt the muriatic acid, which are rendered gasseous by heat. The oxygenated muriatic acid gas exerts such powerful effects on inflammable bodies, that if Phosphorus, Camphor, Alcohol, Æther, or thin leaves of Silver, Gold, or Copper be introduced into it, each of those bodies will instantly take fire.

This gas retains its gasseous form at any common temperature of the atmosphere, but it is readily condensed by cold and absorbed by water. In the latter state it forms oxygenated muriatic acid, which is now generally used for bleaching.

This acid may be obtained for general purposes, although it is not of the purest kind, by the process recommended for fumigation, or by mixing half a pound of common salt with a quarter of a pound of manganese in a bottle with a bent neck fixed to it, then pouring in four ounces of sulphuric acid, diluted with four ounces of water; on applying a gentle heat, the gas will soon pass over, and may be collected in a bottle of water inverted in a vessel of water. A little agitation of the bottle will facilitate the union of the gas with the water, and when a sufficient quantity has been absorbed, it may be corked up for use.

If wine or ink stains, or unbleached cloth be steeped in this fluid, the colour will be expelled without injury to the fabric: this bleaching process is effected through the agency of the oxygen, which is loosely held by the fluid. If it be exposed to the sun's rays in a glass bottle, the acid loses its redundant oxygen, and the fluid becomes useless for bleaching; so that it is necessary to keep it in a common dark green bottle excluded from light, unless used immediately.

Fluoric Acid.

THIS acid united with calcareous earth forms Fluor, or Derbyshire spar.

To separate the acid, pound some small pieces of the spar, and put them into a leaden bottle; then pour in some strong sulphuric acid and apply a sand heat. The sulphuric acid having a greater affinity for the calcareous earth than the fluoric acid, the latter is evolved in the state of gas, which readily unites with water, and may afterwards be concentrated by distillation in a leaden vessel.

Although this acid is so slightly corrosive that it will not injure the skin, yet it has the remarkable property of decomposing Silex or Flint, which no other acid possesses; and as glass contains a considerable quantity of Silex, the acid cannot be kept in glass vessels without dissolving them.

From this peculiar property it is used for amusement, and with some success in the arts, for etching on glass. Take a piece of glass, warm it, and coat its surface with bees' wax; when the wax is cold, etch whatever is intended and pour a small quantity of the acid upon it; this will instantly attack that surface of the glass from which the wax has been removed by the etching needle. The acid may be left on the glass for about half an hour; then wipe off the wax, and a complete etching of the subject will remain.

Designs etched on pieces of thick plate glass may have impressions taken from them on paper, in the same way as from an etched copper plate.

Those who cannot obtain the distilled acid may put some pounded spar into a leaden vessel with half its weight of sulphuric acid, and place it for an hour on the fire in a garden pot filled with sand; then pour off the liquor and keep it in a leaden vessel for use.

It is supposed that there is some analogy between the fluoric and muriatic acids: in one respect they certainly correspond; that is in the great affinity of their respective bases to oxygen, from which they have never yet been separated.

This acid will unite with the oxides of metals, but not with inflammable bodies.

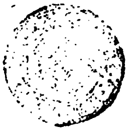
Acid of Borax.

BORACIC acid is obtained from Tincal or crude Borax, which is found in a native state in Africa and India. Tincal is composed of Borax and Soda: these are separated, and the borax purified in this country.

To a solution of borax in boiling water add half its weight of dilute sulphuric acid, then evaporate a portion of the fluid; the remainder on cooling will produce shining scaly chrystals of boracic acid. These chrystals are soluble in alcohol, and the solution burns with a beautiful green flame.

The boracic, like the fluoric and muriatic acid, has not been decomposed; it is amongst the weakest acids, and acts with feeble influence both on metals and their oxides.

Borax is used in melting glass, but more particularly in soldering metals: it cleanses the surface of the metal, and assists the fusion of the solder.



Vegetable Acids.

THESE have compound bases which are formed of Carbon and Hydrogen, and derive their acidity from Oxygen, the other elementary principle of vegetables.

The *Citric Acid* is the pure juice of lemons, which may be obtained by exposing the juice to a freezing atmosphere: this congeals the water, and leaves the acid in its concentrated state.

The *Malic Acid* is obtained from the juice of unripe fruit, particularly apples.

The *Acetous Acid* is common vinegar; a product from the fermentation of saccharine matter.

The *Gallic Acid* exists in nut galls, with Tan and some other substances ; it may be separated from an infusion of galls by muriate of Tin. This acid is also found in many barks, roots and fruits.

There are many other vegetable acids which are not generally interesting; therefore it would be tedious to particularize them in an elementary work ; such are the *Benzoic*, *Oxalic*, *Camphoric*, *Tatareous*, *Suberic*, *&c.* Animal substances also form acids, as the *Lactic*, or *Acid* of *Milk*, *Sebacic*, or *Acid* of *Fat*, *Prussic*, *Bombic*, *Zoonic*, and *Formic Acids*.

Alkalis.

THERE are three alkalis, Potash, Soda and Ammonia; the two former were, until lately, called fixed alkalis, the latter volatile alkali.

The properties common to the three are the change which they produce in vegetable blue colours by turning them green, having an acrid and peculiar taste, rendering oils mixible with water, and readily combining with acids forming neutral salts.

Potash is obtained from burnt vegetables, by washing the ashes and evaporating the fluid, which leaves the solid alkali in chrystals sticking to the vessel. Russia and America, from their immense forests, supply a considerable portion of the potash of commerce.

Dry potash readily imbibes moisture from the atmosphere, which renders it deliquescent.

Soda was formerly obtained from the ashes of marine plants, by a process similar to that for procuring potash; but since common salt is found to consist of muriatic acid and soda, it is more plentifully and conveniently obtained from it.

Potash and Soda being unchangeable by the influence of heat, they were generally supposed, till lately, to be elementary bodies; but the ingenuity and industry of Mr. Davy has discovered that they are compound and decomposable masses, constituted of a metallic base united with oxygen.

This interesting discovery was first effected by means of the Galvanic trough, in the following manner: A small piece of pure potash which had been exposed for a few seconds to the atmosphere to imbibe moisture so as to give a conducting power to its surface, was placed upon an insulated piece of platina connected with the negative side of a large voltaic battery, containing 100 six-inch and 150 four-inch plates in a state of intense activity; a platina wire was likewise brought in contact with the upper surface of the alkali from the positive side of the apparatus.

The potash soon began to fuse at both points of the wire, oxygen gas was given out at the positive end, and small globules, having a high metallic lustre and precisely similar in external character to quicksilver, were produced at the negative end, some of which globules burnt with a bright flame, and exploded as soon as they were formed; others remained only tarnished and covered by a white film that finally pervaded the whole mass of metal, and converted it again into potash. Thus this synthetical process proved the correctness of the analytical experiment; for the white crust that was formed on the surface was produced by the absorption of oxygen from the atmosphere by the metallic base, which converted the body into the same state from which the elements had been separated.

Soda was decomposed by the same process and produced analogous results; but to effect this decomposition it required more intensity of action than the potash.

The combustible and metallic base of fixed alkalis is repelled by surfaces positively electrified and attracted by those that are negative;

but oxygen is attracted by the positively electrified wire of the apparatus, and repelled by the negative end, which shews that the inflammable base of alkalis is in a highly positive, and the oxygen, the other constituent part, in a highly negative state of electricity. It is thus we understand how the decomposition of the body is effected: the positively electrified base and the negatively electrified oxygen have hitherto been held together by such strong affinity that the chemist could not separate them; but from the very opposite states of electricity produced by the voltaic apparatus, the union between the oxygen and base of the alkali is dissolved, and each element combines with its superior affinity, uniting the inflammable base with the negative, and the oxygen with the positive ends of the battery.

From the strong affinity of this metallic base for oxygen, there is considerable difficulty in preventing its recomposition: recently distilled Naphtha is best suited to this purpose, in which the metal may be kept for several days without undergoing any considerable change.

This extraordinary metal forms an imperfect fluid at a temperature of 70 degrees; at 100 degrees it becomes entirely fluid, so that small globules easily run into one another. At 50 degrees it is a soft and malleable solid which has the lustre of polished silver, and at 32 degrees, the freezing point of water, it becomes hard and brittle, with a chrystallized texture. The metal obtained from potash is called Potassium, that from Soda, Sodaum.

The specific gravity of Potassium to water is nearly as 77 to 100. It swims in double distilled Naphtha in a temperature above the freezing point; but sinks when the temperature is below it.

The chemical relations of this body are still more interesting than its physical properties.

When potassium is brought in contact with the least drop of water an instantaneous explosion is produced with a brilliant flame; the water is decomposed, and the result is a solution of pure potash.

If a globule of the metal be placed upon ice it instantly burns with a bright flame, and forms a deep hole, which is likewise found to contain a solution of potash.

So strong is the attraction of potassium for oxygen, that it discovers and decomposes the smallest quantities of water contained in Alcohol or Æther, even when they have been carefully purified.

By forming an amalgam of mercury and potassium, it acts upon gold, silver, and platina, and rapidly revives all metallic oxides. Sodaum, or the basis of soda, is similar in its chemical properties to potassium. The specific gravity of Sodaum is rather greater than that of Potassium; but it is still considerably lighter than water.

100 parts of Soda contain 77 Sodaum and 23 oxygen.

100 parts of potash contain 84 potassium and 16 oxygen.

After Mr. Davy had published to the world this beautiful and interesting discovery, two French chemists, Gay-Lussac and Thenard, hit upon a mode of obtaining Potassium or Sodaum in more considerable quantity than is practicable by the original method of Mr. Davy.

A gun-barrel, with the breech taken out, is bent to the figure of the letter ∽ : a piece of potash or soda in the solid state, is introduced at the breach end into a chamber formed by a plate of iron placed across the tube, with a hole in its centre: when the bent part of the tube is sufficiently heated in the furnace, the alkali melts and drops in small quantity at a time through the aperture upon some iron shavings contained in the barrel below the perforated division; the heat being rendered very intense, the oxygen of the potash, or soda, unites with the iron and forms an oxide of iron, and the metallic basis sticks to the sides of the gun barrel, from whence, when cooled, it is to be collected and introduced immediately into a Phial of Naphtha. In this manner a sufficient quantity may be easily obtained for any chemical experiment.

This discovery of the Alkaline metals has not yet been employed to any advantageous purpose in the arts; but potassium is very useful to chemists as a test for the detection of small quantities of oxygen, an object of great importance in analytical experiments.

Having given an outline of these interesting discoveries, we will now proceed to a consideration of some of the useful purposes to which the alkalis are applied. Soap is formed by uniting the alkalis with tallow or oil. Hard soap is produced by boiling potash, soda, and tallow in water for a considerable time; this ultimately forms a curd, which is poured into moulds to harden, and is afterwards cut out for sale.

The chemical principle on which soap is made is sufficiently explained by putting some oil and rain water into a phial; these will not unite, but if a small quantity of a solution of potash be added, the whole will instantly combine and form a saponaceous fluid; pour in a few drops of any dilute acid, and the oil and water will immediately separate. This process may also serve to explain the difference between what is commonly called hard and soft water. If a solution of soap be made in spring water, a curd is found floating on the surface, which does not occur to a solution made in soft water: this is occasioned by the acids which the spring water has imbibed, together with other heterogeneous matter, in its percolation through the earth. The acid seizes on the alkali of the soap and sets free the fat, which floats on the surface of the water. Those who cannot get soft water may easily render spring water fit for the purpose of washing, by throwing into it a small quantity of wood ashes a short time previous to its being used. The alkali contained in the ashes will combine with the acid, and the water will become as fit for use as the purest rain water.

The acids that are most generally found in well-water are the sulphuric and muriatic: the presence of these acids, and their relative quantities, may easily be detected by tests. If sulphuric acid be present, a drop of a solution of muriate of Barytes will instantly produce a whitish cloud, and by the density of this cloud we may judge of the quantity of sulphuric acid contained.

Muriatic acid is discovered by nitrate of silver. When a drop or two of this solution falls into water containing the slightest portion of muriatic acid, it instantly produces a yellowish cloud, the density of which will be as the quantity of acid.

Vegetable blue colours are tests of the presence of alkalis as well as acids. If a few drops of a solution of potash be poured into syrup of violets, the latter will lose its blue colour and become green. If a few drops of dilute acid be added to another portion of syrup of violets, it will be turned red: yet if this red and green fluid be mixed in proper quantities, the compound will be restored to its beautiful blue colour, by the union of the acid and alkali.

Alkalis and the generality of acids are so acrid and corrosive that the skin or any animal substance is immediately injured by their contact; yet if the acid and alkali be united, they form a third body totally differing in its properties from either of the other two. Take double distilled vinegar and a saturated solution of potash, either of these separately will be found acrid and disagreeable to the taste; but mix them together in proper quantities and the compound will be quite tasteless; nor will it change the blue colour of Litmus or the Violet.

Ammonia.

AMMONIA, or volatile alkali, has for some time been known to be a compound body, formed of hydrogen and nitrogen; existing as a gas in its purest state. Mr. Davy supposes that in addition to the two preceding elements, it contains about seven or eight per cent of oxygen.

There is so much reason to believe that all the alkalis possess oxygen as well as acids, that this element may now be considered to be a principle of alkalescence as well as of acidity. Indeed it seems more than probable that all bodies are constituted of different portions of oxygen and an inflammable base, united by the opposite states of electricity which they possess.

Ammoniacal gas may be obtained by mixing equal parts of muriate of ammonia and quicklime in powder. The compound being put into a gas bottle, when the heat of a lamp is employed, the ammonia will be plentifully liberated; but will only remain permanent over mercury, being immediately absorbed by water.

This gas is fatal to animals; has a very pungent smell, and instantly extinguishes flame. It is lighter than atmospherical air, and will not explode when mixed with hydrogen gas.

The liquid ammonia is formed by the rapid absorption of ammoniacal gas by water. If two or three drops of water be admitted into a jar of ammonia, the whole of the gas will be instantly absorbed. The gas is given out again from liquid ammonia by heat.

When ammoniacal gas is mixed with acid gases, a cloud is produced, formed of ammoniacal salts. This is very apparent when muriatic acid gas is employed. In the separate state of these two gases, they are completely invisible; but the instant they are suffered to enter into union, a dense white cloud is diffused throughout the vessel.

Earths.

THESE bodies are divided into two kinds, called alkaline and simple earths.

The alkaline earths are Barytes, Strontites, Lime, and Magnesia.

The simple earths, Silex, Alumine, Zircon, Glucine, and Yttria.

These were, till lately, considered as elementary bodies ; but the electro-chemical apparatus not only shews the alkalis to be compounds, but likewise the alkaline and simple earths, as they have been generally called, are found to possess a metallic base united with oxygen.

The specific gravity of the heaviest earth does not exceed five times the weight of water;

whereas Tin, which is the lightest ordinary metal, is seven times heavier than Water. What particularly distinguishes earths, is their affinity for acids, and the various products resulting from them : but as these combinations will be noticed in their proper place, we will now only state the general character of the earths; and first of *Barytes*. This substance from its weight, which is five times that of water, has been called ponderous earth. It has a sharp caustic taste, and, like the alkalis, unites oil and water: it changes vegetable blue colours to green, and fresh prepared Barytes has such affinity for water, that when water is poured upon it, the fluid is rapidly absorbed, and an abundant quantity of heat is evolved. This union produces a very tenacious cement. Boiling water will dissolve half its weight of Barytes ; it likewise dissolves in alcohol, and then burns with a yellowish flame. Barytes is a most virulent poison.

Strontites. This earth has its name from Strontian, the place where it was first discovered; since which it has been found in different parts of Europe. It is obtained from its carbonate by an intense heat; it has a greyish appearance, and is very acrid and caustic, but in a less degree than either Potash, Soda, or Barytes.

Strontites is readily soluble in boiling water, and forms regular chrystals as the water cools: it is likewise soluble in Alcohol, and gives a curious blood-red flame when the boiling alcohol is set on fire.

From the great analogy between Barytes, Strontites, Potash, and Soda, the two former have been ranked as alkalis by some eminent chemists.

Lime when fresh from the kiln is white and brittle, has a hot burning taste, corrodes animal and vegetable substances, and turns vegetable blue colours green. Its specific gravity is twice that of Water.

When water is poured on fresh lime a prodigious quantity of heat is evolved; and in 100 lbs. of lime 28 lbs. of water will be totally absorbed, so that the mass will be solid.

The heat which is produced by what is called slaking of lime, arises from the chemical union of the water with the earth. This affinity occasioning the water to take a solid form, the heat which previously kept it in a state of fluidity is set free, and so abundantly, that it frequently sets fire to wood or any inflammable body in contact with the slacking lime.

A considerable quantity of vapour is likewise driven off, and with this a small portion of lime; for paper stained with violets held in the vapour is turned green.

Water will dissolve about a 500th part of its weight of lime; it is then called lime-water. Lime has great affinity for carbonic acid; when united with this acid it is called carbonate of lime. Chalk, limestone, and marble are carbonates of Lime: these being exposed for some time to a red heat in a kiln, the carbonic acid is driven off in the form of gas, leaving the alkaline earth in a highly caustic state. Lime combines with all the acids, likewise with Sulphur, Phosphorus, and the metallic oxides.

Magnesia is ranked amongst the alkaline earths, but it has less of alkalescent properties than any of those that have been mentioned. When magnesia is pure, it is very light, white, and tasteless. It combines with acids, but is more easily separated from them than any of the earths that have been noticed, although it produces an intense heat and red light when suddenly mixed with concentrated sulphuric acid. It combines with water very sparingly; not exceeding a 2000th part of the weight of the water.

Silex is one of the simple earths, and is that substance which forms the principal part of flints, rock chrystal, and some of the gems. Pure silicious earth in powder is perfectly white and tasteless; insoluble in water, and has a dry and harsh feel to the fingers. It is not acted upon by any other than the fluoric acid, which completely dissolves it.

Silex fused with potash or soda forms glass; but in the making of this article for commerce other ingredients are mixt with the silex besides alkali. Fine glass is composed of 16th parts flint, 8 pure potash, 6 coloured borax, 3 flake white, and 1 nitre.

When too much potash is put into glass, it attracts moisture from the atmosphere, and it has sometimes happened that a large looking glass has dropt out of its frame and become so soft as to be easily crumbled to pieces by the fingers.

When silex is completely dissolved in alkali, it is called liquor of flints: we are told that a piece of rock chrystal has been formed in this fluid, by leaving it undisturbed for seven or eight years.

Alumine constitutes a principal part of common clay, and likewise forms the greatest portion of Alum. From this last mentioned substance it is obtained in its pure state. Alumine is smooth, has an unctuous feel, and sticks to the tongue: It is diffusible, but insoluble in water.

Zircon was discovered in a stone in Ceylon, called Jargon; it likewise forms a part of the stone called Hyacinth. Zircon is white and harsh to the feel like silex, but without either taste or smell. It is insoluble in water, and unites with carbonic, nitric, and sulphuric acids; it is fusible in a strong heat, and becomes so hard as to strike fire with steel, and scratch glass.

Glucine, like Zircon, is a recent discovery, and is found to exist in the Beryl and Emerald. It forms a white soft powder which sticks to the tongue like alumine; it is infusible by heat, insoluble in water, has no action on blue vegetable colours, and combines with the different acids.

Yttria, like the two preceding earths, has no property, either interesting or useful to the general inquirer. It was first discovered in a stone called Ytterby, found in Sweden. It is white, and has neither taste nor smell; infusible alone, but forms a white glass with borax, and is insoluble in water. Its specific gravity is near 5 times that of water. It is soluble in most acids, but is not acted upon by the alkalis.

Neutral Salts.

THIS extensive and useful class of bodies might have been introduced under the heads of acids, alkalis, or earths, from which they are formed; but it is considered a preferable mode to place them under one head, to simplify as much as possible, the account of the respective bodies from whence they are derived.

Salts are formed by the union of the different acids, with alkaline, earthy, and metallic bases: different quantities of oxygen may combine with these bases; when they are fully saturated, the termination is in *ate*, as sulph-ate of soda; but when the base receives an inferior quantity of oxygen, the word terminates in *ite*, as sulph-ite of potash.

The present names of chemical compounds have great advantage over those they formerly possessed: for instance, sulphate of soda was called Glauber's Salt; this merely indicates that it was a salt made or discovered by a person of the name of Glauber, without informing us of any circumstance belonging to the preparation itself: but the new nomenclature tells us that it is a chrystallized mass, formed by the union of sulphuric acid with the alkali soda: that salt-petre is a nitrate of potash, and common culinary salt, muriate of soda.

SULPHATES are neutral salts produced by the union of sulphuric acid with particular bases.

Sulphate of Potash, formerly called *Vitriolated Tartar*, has a penetrating bitter taste, is soluble in hot and cold water, and is volatalized when thrown on red hot iron. It does not exist in a natural state, nor has it yet been applied to any useful purposes. 100 parts contain 30 acid, 65 alkali, and 5 water.

Sulphate of Soda, or *Glauber's Salt*, has a bitter, cool, and saline taste. It is found abundantly in sea water, and likewise in an efflorescent state upon old walls, and upon the surface of the earth. When exposed to the air it loses its water of chrystallization, and the chrystals fall into a white powder. Water dissolves it very readily; hot water will take up nearly its own weight; but a considerable portion of the salt will again chrystallize on cooling. 100 parts of this salt contains 27 acid, 15 soda, and 58 water.

Sulphate of Ammonia, or *vitriolated volatile Alkali,* has a bitter taste, and is slightly deliquescent: it is not known in a natural state, but is formed by the direct union of sulphuric acid with ammonia. Two parts of cold water take up one of this salt, and hot water will dissolve its own weight. 100 parts contain 55 acid, 14 ammonia, and 31 water. Its use is very limited, being chiefly prepared for chemical experiment.

Potash and Soda having stronger chemical affinity for sulphuric acid than ammonia, the salt is decomposed by these alkalis, and the ammonia set free.

Sulphate of Barytes, or *ponderous Spar,* has a stronger affinity for sulphuric acid than any other of the alkaline bodies, so that it will take this acid out of its combination with any other substance. If a few drops of a solution of Barytes in muriatic or nitric acid be let fall into water containing the smallest quantity of sulphuric acid, it will instantly unite with it, and form a dense white cloud; and as spring water generally contains some portion of sulphuric acid, a solution of Barytes, in muriatic acid, is commonly used as a test to detect the relative quantity of the sulphuric acid which is contained in the water.

The sulphate of Barytes is the heaviest of all the salts; it is found abundantly in the interior of mountains, and is without taste or smell. It contains 25 parts acid, and 75 earth. Its specific gravity is about 4½. The Bolognian phosphorus is formed from this sulphate by decomposition at a red heat.

Sulphate of Strontites resembles, in its general properties, the sulphate of Barytes: It is very insoluble in water, and has a great affinity for sulphuric acid.

The sulphate of Strontites is found in considerable quantities in the neighbourhood of Bristol.

Sulphate of Lime: Selenite or Gypsum, is of a white colour. When it is burnt it absorbs water rapidly, and almost instantaneously forms a hard solid mass. There are very few saline bodies that are so plentiful in nature as sulphate of lime; it sometimes forms entire strata in mountains; it is likewise found in mineral waters, and in the ashes of vegetables. It is sparingly soluble in water, but is decomposed by the alkalis which unite with the sulphuric acid, and throw the lime out of combination. 100 parts contain 46 acid, 32 Lime, and 22 water. Sulphate of lime is called Plaister of Paris when it is burnt and pulverized: this is mixed with water and poured into moulds to form images, bass-relievos, mouldings, &c.

Sulphate of Magnesia, or *Epsom Salt*, forms the basis of many purgative and mineral waters; it has a very bitter taste, and is decomposed by Lime and Barytes, which take the acid out of its combination with the magnesia. This salt is seldom prepared artificially, as nature presents it in sufficient quantities for any purposes to which it may be applied. 100 parts contain 33 acid, 19 magnesia, and 48 water.

Sulphate of Alumine. Alum was formerly considered as a sulphate of Alumine, but it is now found to be a triple salt containing sulphuric acid, Alumine, and a little potash, or ammonia;

sometimes both. The Alum of commerce contains in 100 parts, 49 sulphate of alumine, 7 potash, and 44 water. It has an astringent taste, and reddens vegetable blues; it is soluble in cold water, and boiling water dissolves ¾ of its weight. This salt is very useful in the arts, particularly in dying and callico printing, where it is used to fix particular colours.

A combination of alumine, sulphur, and charcoal, forms Homberg's Pyrophorus, which is a light black powder that takes fire on pouring it out of a bottle into the air: it inflames with great rapidity in oxygen gas.

Sulphate of Glucine. This earth readily combines with sulphuric acid, and forms a very soluble salt, which has a sweet and rather an astringent taste.

Sulphate of Zircon is a white insoluble tasteless salt, which is decomposed by heat, and readily yields its sulphuric acid to the alkalis.

Sulphate of Yttria chrystallizes in small grains of a light red colour; has a sweet taste, and requires 50 parts of cold water for its solution.

SULPHITES are salts formed by sulphureous acid with different bases. The sulphureous acid has less oxygen than the sulphuric.

The sulphites are not native productions; but are fabricated in the laboratory of the chemist: they possess a sharp disagreeable sulphureous taste, and are decomposible by fire. All the sulphites absorb oxygen more or less, by which means they become sulphates, with an increase of weight according to the quantity of oxygen taken up. Sulphites burn with great rapidity when they are mixed with oxygenated muriate of potash. This class of bodies has hitherto been found useless in the arts, and as they possess no interesting or amusing chemical properties, this brief outline will be sufficient.

SULPHURETS are formed by mixing and fusing sulphur and some alkaline base together.

Sulphuret of Potash, or *Liver of Sulphur,* as it has been called, is obtained by melting two or three parts of the alkali with one of the sulphur; the mass has a liver coloured appearance from whence it has obtained its name.

Sulphurets although hard when they are first formed, soon imbibe moisture from the atmosphere, and become soft, emitting a disagreeable smell, much like that of rotten eggs. They change the vegetable blues, green, and blacken the skin, silk, and animal substances.

Sulphurets are decomposed by the acids, and in their liquid state absorb oxygen gas, which uniting with the sulphur, forms sulphuric acid; this combines with the alkali of the sulphuret and forms sulphate of potash.

NITRATES are formed by the combination of Nitric acid with particular bases.

Nitrate of Potash, usually called Nitre or Salt Petre, may be artificially produced by the union of nitric acid and potash, which on evaporation, yields chrystals of salt petre: but this important and well known salt is one of those most frequently found in a native state. Spain and the East Indies afford the greatest supply. It also exists in several parts of America. It is artificially obtained by spreading on the surface of the earth, animal, vegetable and earthy substances, which putrify and give out nitrogen. This gas united with oxygen, produces nitric acid, and the acid combining with the alkaline matter in the earth, forms nitrate of potash.

This salt is likewise spontaneously produced in an efflorescent state on old walls, stables, dove-houses, and other places that are frequently moistened with animal fluids or vapours: soft calcareous stones have frequently the property of producing salt petre; and on the old mortar of uninhabited houses it is almost invariably to be found.

Nitrate of potash has a cool, penetrating, and bitter taste, by which it is easily distinguished. Hot water will take up its own weight of this salt: When thrown upon red hot iron, it gives out a white flame. With a moderate degree of heat it fuses, and the water of chrystallization being driven off, and the melted salt poured into moulds, it forms what is commonly called Sal Prunella. 100th parts of Nitrate of Potash contain 30 nitric acid, 63 potash, and 7 water.

Every pound of nitre yields 12000 cubical inches of oxygen gas; it is on this account that salt petre is employed with sulphur to make sulphuric acid, the quantity of oxygen evolved from the nitre being sufficient not only to support the combustion, but likewise to unite with the sulphur, forming sulphuric acid.

Burning charcoal likewise decomposes nitric acid. If nitrate of potash be mixed with charcoal and set on fire, detonation ensues, and the nitric acid contained in the salt is decomposed. The oxygen of the acid unites with the charcoal and forms carbonic acid gas, and a portion of this carbonic acid unites with the alkali of the nitre, and forms carbonate of potash.

A mixture of five parts nitre, one sulphur, and one powdered charcoal, carefully rubbed together with a sufficient quantity of water to keep them from igniting, and afterwards granulated and dryed, forms Gunpowder. The advantage of the sulphur seems to consist in the facility which it gives to the ignition of the other materials.

The prodigious force of gunpowder arises from the expansive power of the gasses which are generated by the combustion of the ingredients. The Residuum after the explosion, consists of sulphate of potash, and a small quantity of carbonate of potash.

A mixture of three parts powdered nitre, two of carbonate of potash, and one of sulphur,, forms a fulminating powder, which explodes with a loud noise when laid on heated iron.

Nitrate of Soda is not a natural production, but is formed by the union of nitric acid with soda. It has a cool bitter taste, is rather deliquescent, and burns with a yellow flame. 100 parts contain 29 acid, 50 soda, and 21 water. This salt has not yet been employed for any useful purpose.

Nitrate of Ammonia is produced by uniting nitric acid gas with ammoniacal gas, which forms a white cloud that subsides and chrystallizes on the sides of the vessel. The most simple and easy way of obtaining this salt is by putting carbonate of ammonia into diluted nitric acid: the ammonia unites with the nitric acid, in preference to the carbonic acid, and when the fluid part is driven off by evaporation, chrystals are formed of nitrate of ammonia. When this salt is thrown upon heated iron, it melts, produces a vivid flame, and explodes with considerable noise. 100 parts contain 75 acid, 19 ammonia, and 6 water.

If this salt, which is a dry and solid mass, be rubbed in a mortar, with an equal quantity of muriate of lime, these two solid bodies immediately unite and form a perfect fluid.

But what most particularly distinguishes the nitrate of ammonia, is the gas called nitrous oxide, which is produced from it.

This salt is decomposed in a glass retort, by the heat of a spirit lamp; and the gas which is generated is collected in a proper vessel for use. Oxygen and nitrogen are the elementary principles that form it; but they are united by electricity, and exist in different proportions from those in which they are found in atmospheric air.

When the Nitrous Oxide is included in a bladder or silk bag, and respired for some little time, it produces remarkable effects, much resembling intoxication; but with this striking difference, that it leaves no lassitude or indisposition after its exhilarating effects have ceased: on the contrary, it seems in many instances to leave an additional energy.

The sensations are different in different persons, and seem in some measure to be governed by the natural disposition of those who take it: if they are naturally lively and cheerful, it never fails to produce great exhilaration, and generally makes the person dance and jump about in a ludicrous manner; those of a more serious or grave character are not so violently affected;

and instances occasionally occur in which the gas produces no sensation at all.

Nitrate of Barytes has not been found in a native state; but is obtained by dissolving the native carbonate in nitric acid. It requires 3 or 4 times its weight of hot water for its solution, and is not altered by exposure to the atmosphere. In a red heat, the acid is driven off, leaving the Barytes in a very caustic state. 100 parts contain 38 acid, 50 Barytes, and 12 water.

Nitrate of Strontites may be obtained in the same way as the nitrate of Barytes. The solubility of this salt is very considerable: cold water dissolves an equal weight of it, but boiling water takes up twice its own weight. It communicates a deep red flame to boiling Alcohol. 100 parts have 49 of acid, 47 Strontites, and 4 water.

Nitrate of Lime is plentifully found in the mortar of old buildings; it is embodied in calcareous stones, and dissolved in mineral springs. Nitrate of Lime is artificially prepared by pouring dilute nitric acid on carbonate of lime: it has a sharp and bitter taste, readily deliquesces, and is very soluble in water. When this salt has been exposed to the sun for a few hours, it gives a phosphorescent appearance in the dark. 100 parts contain 43 acid, 32 lime, and 25 water.

Nitrate of Magnesia is likewise found in a native state in old walls; it is very deliquescent, has an acrid bitter taste, and is very soluble in water or Alcohol. 100 parts contain 36 acid, 27 magnesia, and 37 water: it is artificially prepared by dissolving carbonate of magnesia in nitric acid, and then evaporating the solution.

Nitrate of Alumine is obtained from fresh precipitated alumine dissolved in nitric acid, which chrystallizes on evaporation. It has an astringent taste, and is deliquescent.

Nitrate of Glucine does not chrystallize, has a sweet taste, absorbs moisture abundantly, and is decomposed without fusion at a high temperature.

Nitrate of Zircon is very soluble in water, has an astringent taste, and forms a yellow transparent mass, which is extremely tenacious, and long retains that quality.

Nitrate of Yttria is obtained by dissolving Yttria in nitric acid: it possesses a sweetish astringent taste; may be obtained in imperfect chrystals, but soon becomes fluid by exposure to the atmosphere.

NITRITES are formed by depriving the nitrates of a part of their oxygen; but there is nothing sufficiently interesting or useful in this class of salts to render it necessary to notice their individual characters in this work.

MURIATES are Salts formed by the union of Muriatic acid with different bases.

Muriate of Potash exists in a native state. It is found in old plaister, sea water, and in vegetable and animal fluids. Muriate of Potash has a strong bitter taste, and dissolves in 3 times its weight of water. In 100 parts are 30 acid, 64 alkali, and 6 water. It is artificially produced by saturating muriatic acid with carbonate of potash, and evaporating it to chrystallization.

Hyper-oxygenated Muriate of Potash is formed by bringing the oxygenized muriatic acid gas, which has already been described, into union with potash. If this gas be introduced to the alkali in a proper apparatus, one portion of the gas will yield its oxygen to the other, and the deoxygenized part will simply form muriate of potash. The other portion of the gas will likewise unite with the alkali, not only with its own oxygen, which would form oxygenized muriate of potash, but also with the oxygen of the first portion: this double quantity of oxygen will form the hyper-oxygenized salt, and as these chrystals are produced much quicker in the alkaline solution than those of the muriate of potash, the two salts may be easily separated.

Hyper-oxygenized muriate of potash contains 65 parts in 100 oxygen in addition to the oxygen presumed to be contained in the muriatic acid; the oxygenized acid only contains 16 per cent.

This salt is decomposed by acids. If a small portion be put in concentrated sulphuric acid, an explosion takes place. This experiment cannot be generally recommended to young students of chemistry, on account of the danger that attends it.

Heat separates the oxygen of this salt from its base; and this is probably the purest state in which oxygen gas can be obtained.

Hyper-oxygenized muriate of potash exerts powerful effects on inflammable bodies.

If two grains be rubbed in a mortar with about half the quantity of sulphur, it will produce a loud cracking noise: the detonation is still stronger if it be enclosed in a piece of paper and struck upon an anvil.

If some of the powdered salt be mixed with powdered sugar, a drop or two of strong sulphuric acid will suddenly set it on fire. The same experiment succeeds with charcoal or camphor.

If a piece of phosphorus be put at the bottom of a wine glass of water, with a small quantity of the salt, on pouring in a few drops of sulphuric acid, the phosphorus will continue flashing light for some time at the bottom of the glass.

If a grain of phosphorus be rubbed in a mortar with two grains of the salt, a violent detonation will immediately take place. This is a dangerous experiment, as the ignited phosphorus sometimes flies about the room.

From the abundant quantity of oxygen contained in this salt, it is employed with more advantage than nitre in making gunpowder; but the great difference of price is an impediment to its adoption. There is also greater danger in the manufacture of the gunpowder.

Muriate of Soda, or *Common Salt*. This is a most plentiful production of nature; it gives saltness to the ocean; it likewise exists most abundantly in a solid chrystallized state in many parts of the earth, particularly in Poland and Hungary. From the immense beds of marine shells and madrepores which are constantly found in the neighbourhood of salt rocks, it seems probable that these saline concretions have been produced by the evaporation of sea water, under some prodigious convulsion of nature.

Salt has a penetrating pleasant taste; is soluble in 2½ times its weight of cold water, and hot water takes up but very little more. In 100 parts are 43 acid, 46 alkali, and 11 water.

When muriate of soda is heated gradually, it fuses, and as it cools, forms itself into a solid mass; but decrepitates when thrown suddenly into the fire, or upon red-hot iron. It is not decomposed by combustible bodies, as the oxygen which it contains, has more affinity for the base with which it is united, than for these bodies.

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Sodium —

Carbonate of Potash decomposes common salt. The muriatic acid having greater affinity for potash than soda, unites with it, and forms muriate of potash; whilst the carbonic acid unites with the soda, and forms carbonate of soda. Salt may likewise be decomposed by nitric acid and oxide of lead.

Muriate of Ammonia, or *Sal Ammoniac*, is found in a native state in the neighbourhood of Volcanos; but for the general purposes of commerce, it is obtained from soot, bones, horns and different animal substances.

If ammoniacal gas and muriatic acid gas be mixed together over mercury, they immediately form a white cloud which condenses into a solid mass on the sides of the vessel; this is muriate of ammonia: it has a sharp acid taste, dissolves in 3½ times its weight of cold water, and 100 parts contain 52 acid, 40 ammonia, and 8 water.

Muriate of Ammonia is decomposed by lime: the muriatic acid having more affinity for the lime than the ammonia, the latter is set free in a gasseous state, which has a sharp pungent smell. This salt is likewise decomposed by Potash, Soda, Barytes, and Strontites.

Muriate of Barytes is obtained by dissolving carbonate of Barytes in muriatic acid: the nitric and sulphuric acid take it out of combination with the muriatic, particularly the latter; this makes muriate of Barytes very useful as a test in detecting the smallest quantity of sulphuric acid which may exist in water.

This salt is very poisonous; it has a bitter and nauseous taste, containing in 100 parts, 60 Barytes, 24 acid, and 16 water.

Muriate of Strontites may be obtained by the same process as the muriate of Barytes: it is soluble in 2 parts cold water, and almost to any amount in hot: it dissolves in Alcohol, to which it gives a red coloured flame. In 100 parts are 37 Strontites, 24 acid, and 40 water.

Muriate of Lime. This salt is produced by dissolving carbonate of lime, or common chalk, in muriatic acid. It exists in a native state in the sea, and in some mineral waters. 100 parts of lime will take up 86 of muriatic acid: it is very deliquescent; dissolves in half its weight of cold water, and almost to any extent in hot.

If a solution of muriate of lime be poured into a solution of potash, they are immediately converted into a solid mass. When concentrated sulphuric acid is poured upon a strong solution of this salt, it instantly solidifies, and gives out an abundant quantity of heat.

Muriate, like the Nitrate of Lime, communicates a red flame to Alcohol. When united with light fresh fallen snow, these two masses have such disposition to liquify, and so greedily absorb caloric, that a diminished temperature of more than 40 degrees below the zero of Fahrenheit's thermometer, may be obtained by this means. If quicksilver be put in a thin glass tube, it may be frozen and rendered solid at this temperature.

Muriate of Magnesia has an acrid bitter taste; it is found in a native state in sea water, and in salt mines. It is soluble in an equal weight of water, and is decomposed by heat at high temperatures. 100 parts contain 34 acid, 41 magnesia, and 25 water.

Muriate of Alumine is produced by precipitating alumine in muriatic acid; it chrystallizes with great difficulty, and has a bitter and acrid taste.

Muriate of Glucine is hardly chrystallizable, and has a sweet taste like the other combinations of Glucine.

Muriate of Zircon has a sharp taste, is very deliquescent, and is easily decomposed by fire.

Muriate of Yttria closely resembles the nitrate of this earth.

CARBONATES are formed by the union of carbonic acid with different bases; they are not deliquescent by exposure to the atmosphere, and the affinity between the acid and its base is so weak as to be easily separated by heat only.

Carbonate of Potash is obtained by introducing carbonic acid gas into a solution of this alkali, until it is saturated. This, when chrystallized, forms a salt, containing in 100 parts, 23 acid, 70 alkali, and 5 water.

Carbonate of Potash is decomposed by lime, which unites with the acid, and leaves the alkali in its simple state.

Alkalis having an affinity for carbonic acid, easily obtain it from the atmosphere, and thus by an incomplete saturation, form sub-carbonates. The potash and soda of commerce are on this account sub-carbonates. To obtain the alkalis in a pure and caustic state, they are to be exposed to a strong heat, which drives off the carbonic acid in the state of gas, and the alkali must then be immediately excluded from contact with atmospheric air.

As the alkalis of commerce are frequently adulterated, the quantity of real alkali contained in any given weight of potash or soda is known by saturating it with sulphuric acid. For example, suppose two alkalis are to be examined of equal weight; one takes two ounces of acid to saturate it, and the other three; the latter contains more real alkali than the former, in the proportion of the additional quantity of acid.

Carbonate of Soda may be obtained by a similar process to that which produces carbonate of potash, and exists also in two states, namely, the carbonate and sub-carbonate. That which is commonly sold in the shops is the sub-carbonate, which is much more acrid and caustic than the carbonate or saturated salt. 100 parts of carbonate of soda contain 39 acid, 38 soda, and 23 water.

Carbonate of Ammonia, or *Concrete Volatile Alkali*, is obtained by the union of carbonic acid with ammonia. If a vessel filled with carbonic acid gas be mixed with a vessel of ammoniacal gas, which is the pure state of ammonia, a white cloud is instantly produced, and a concrete mass is deposited on the sides of the glass; this is the carbonate of ammonia: or it may be obtained by distillation from a mixture of ammonia with carbonate of potash. This salt contains in 100 parts, 45 acid, 43 alkali, and 12 water.

The carbonate of ammonia is decomposed by potash or soda, which takes the acid from the ammonia.

Carbonate of Barytes is a native production, and nearly insoluble in water. Barytes has great affinity for carbonic acid, and retains it at high temperatures. Carbonate of barytes is found in white or greyish white semi-transparent masses, which are not affected by the atmosphere. It is extremely poisonous, and contains in 100 parts, 80 barytes and 20 acid. It is decomposed by the sulphuric, nitric, and muriatic acids.

Carbonate of Strontites is found in a native state at Strontian, in Scotland, where it was first discovered. It very much resembles barytes in its strong affinity for carbonic acid. It loses a part of its acid by heat, and communicates a purple flame to coals. Carbonate of strontites contains in 100 parts, 30 acid, 62 strontites, and 8 water.

Carbonate of Lime. Common chalk, marble, lime-stone, calcareous spar, or stalactites, are all formed by the union of carbonic acid with lime or calcareous earth.

Lime has such a strong affinity for carbonic acid that it will take it up from potash or soda. Fresh burnt lime imbibes moisture and carbonic acid from the atmosphere: the causticity of the lime diminishes, as its union with the carbonic acid increases.

Carbonate of lime is decomposed by the stronger acids. If common chalk has dilute sulphuric acid poured upon it, an abundant quantity of carbonic acid is instantly liberated. This is the usual mode of obtaining carbonic acid for chemical experiments.

Chalk is properly only a sub-carbonate. When the lime is fully saturated, it is then called a carbonate. In this state it contains 55 lime, 34 acid, and 11 water.

Carbonate of Magnesia. Magnesia has a very weak affinity for carbonic acid, so much so that it will not take it from the atmosphere in any material quantity.

Sub-carbonate of magnesia may be saturated by keeping it mechanically suspended in water, passing carbonic acid at the same time through the mixture; when this solution is evaporated, it yields small chrystals of carbonate of magnesia. The sub-carbonate contains in 100 parts, 34 acid, 45 earth, and 21 water. The carbonate, 50 acid, 25 earth, and 25 water.

Carbonate of Glucine is an insipid and insoluble light white powder, which readily loses its carbonic acid by exposure to heat.

Phosphates. Phosphoric acid unites with alkaline and earthy bases, which form phosphates. The phosphoric acid is obtained by the union of phosphorus with oxygen during combustion.

Phosphates are soluble in the nitric and muriatic acids, and are precipitated from these combinations by lime-water and ammonia.

As these salts are of little interest or utility they may be all passed over, saving *phosphate of soda*, which Dr. Pearson has introduced into medicine as a purgative; its chief value for this purpose depends on its insipidity.

Phosphate of Lime forms a considerable part of bones, and exists in other animal substances. It is a white opake mass, both insipid and insoluble in water.

Phosphuret of Lime which is obtained by the mixture of phosphorus and lime, by the aid of heat, is interesting from its power of decomposing water, producing phosphuretted hydrogen gas. If some pieces of fresh phosphuret of lime be put into warm water, phosphuretted hydrogen gas immediately arises to the top and takes fire as soon as it comes in contact with the atmosphere. This flashing will continue for a considerable time, and as the smoke rises it forms dense white rings. The great objection to this experiment is the disagreeable smell of the gas.

Various metals unite with the acids and form metallic salts, which will be noticed under the heads of the respective metals, in the following part of this work.

Metals.

THESE are simple, heavy, brilliant, and opake bodies; good conductors of electricity, and exceed the specific gravity of water not less than 6 times. Some of them possess malleability, that is to say, are capable of being beaten out; others ductility, or may be drawn into wire, and a few have neither the one property nor the other.

From recent additions we now reckon twenty-eight distinct metals; these have been variously arranged. Dr. Thompson has lately divided them into four classes.

The first; those metals that are capable of being beaten out, and of this description are *Platina, Gold, Silver, Mercury, Palladium,* *Rhodium, Iridium, Osmium, Copper, Iron, Nickel, Tin, Lead,* and *Zinc.*

The second class consists of those that are brittle and easily fused, which are *Bismuth, Antimony, Tellurium* and *Arsenic.*

The third consists of metals that are brittle and fused with difficulty: Of this kind are *Cobalt, Manganese, Chrome, Molybdena, Uranium,* and *Tungsten.*

The fourth class is composed of what are called refractory metals, or such as have never been obtained in their pure metallic form, but always remain in combination with oxygen, forming metallic oxides: of this description are *Titanium, Columbium, Tantalium,* and *Cerium.*

The capability of uniting with oxygen belongs generally to all metals, although the combinations and results, with different metals, vary considerably.

Manganese and arsenic will oxydate or unite with oxygen by mere exposure to the atmosphere at a common temperature; and iron, zinc, copper, tin, and lead dispossess the atmosphere of its oxygen when they are considerably heated; but there are other metals, such as platina, gold, and silver that will not oxidize with the most violent heat, although small portions of these metals, in the form of wire or leaf, will oxidize by common electricity, and with still greater facility, by means of the voltaic trough.

There are some metals which are oxydized by the decomposition of water. The oxygen of the water being taken from its combination with the hydrogen. The red rust on iron exposed to damp, is formed in this manner: When red-hot iron is immersed in water, the latter is instantly decomposed, and the weight of the iron is increased by the weight of the oxygen taken up.

Iron oxidizes very rapidly in oxygen gas, and burns with great brilliancy. The weight of the oxide, or cinder, will be found to be heavier than the wire which is burnt by the weight of the oxygen which has been consumed.

All metals are capable of oxidizement in acids. Those that will not take up oxygen from air or water by the influence of heat, oxidate in particular acids. Gold will not dissolve in nitric or muriatic acid alone, yet it yields to a compound of these acids.

Oxidized metals hold their oxygen with different degrees of affinity. Some metals give back their oxygen by heat only; others require the addition of a third body. Charcoal, for instance, is employed in the deoxydation of iron. Under the influence of heat, the oxygen of the iron unites with the charcoal, and forms carbonic acid; during which, the iron is restored to its metallic state. This operation is termed the reduction or revival of a metal.

Metals which are dissolved in acids, are revived by alkalis. Iron combines with sulphuric acid, and forms a salt, called sulphate of iron. The iron is obtained from this combination by pouring a solution of alkali into a solution of the salt, which precipitates the metal. In some cases one metal will revive another. If a piece of iron be put into a solution of nitrate or sulphate of copper, the copper is precipitated, and forms a coating upon the iron.

Metals are found in three different states, either pure or oxygenized, or combined with sulphur or arsenic. The state of oxide is the most usual.

The metal is taken out of its combination with arsenic or sulphur, by what is called roasting, that is, exposing the mass to a low red heat.

The oxides of metals are reduced by submitting them to a strong heat with charcoal, or some other substance that has a stronger affinity for oxygen, than the metal with which it is combined.

Fluxes, or substances which readily run into fusion, are used to unite the parts of metals into a solid mass. Two parts of tartar and one of nitre, form what is called the black flux, and equal parts, the white flux.

When sulphur is found united with metals, they are called pyrites, or metallic sulphurets. Iron pyrites, or sulphuret of iron, is the most common.

Many of the metals mix with one another, and form alloys.

Metals have an affinity for phosphorus, and combine with it, forming phosphurets. Iron combines with carbon, and forms a carburet of iron. All metals, except gold, combine with sulphur, and form sulphurets. Some of the oxides of metals will combine with sulphuretted hydrogen, and form hydro-sulphuretted oxides.

Platina is imported into this country in small grains, which are nearly of the colour of tin; these grains are tolerably pure. They are brought from Peru, and are found amongst gold ore.

Platina is exceedingly difficult to fuse, but will yield to the blow pipe when it is supplied with oxygen gas. It is 23 times heavier than water, consequently the heaviest body known. gold, which ranks next, is only 18 times the weight of that fluid. From the great infusibility of platina, it is used with much convenience in forming crucibles and other chemical utensils that are to be exposed to a violent heat.

Different metals conduct heat with different degrees of facility. Platina is a bad conductor of heat when compared with some other metals. Dr. Wollaston coated three rods with wax; one of silver, a second of copper, and the third of platina; the end of each was equally heated, and, in the same time, the wax was melted 3¼ inches up the silver rod, 2½ up the copper, and only 1 inch up the platina rod.

Platina will weld, that is, the two ends of a rod, or bar, may be united by heat and hammering, which is a property that only belongs to this metal and iron.

Nitro-muriatic acid and oxygenated muriatic acid will dissolve platina, as well as gold. A saturated solution of platina in nitro-muriatic acid is of a dark red colour: the metal is precipitated from this solution by muriate of ammonia.

As the muriate of ammonia will not precipitate gold from its solution in these acids, a mixture or an alloy of gold and platina may be separated by dissolving it in either of the preceding acids, and afterwards precipitating the platina by the muriate of ammonia. Platina unites generally with the other metals.

A solution of tin is a good test of platina. If there be the smallest portion of the latter metal in solution, a drop of the solution of tin detects it, by giving a bright red colour to the fluid.

Gold is the most ductile and malleable of all the metals. One grain of gold may be beaten out into a surface of 56 square inches; and an ounce of gold would make upwards of 20000 miles in length of gold wire. Its specific gravity is 18. It exists in a variety of bodies, and it is even stated to have been found in vegetables.

Great quantities of gold are brought to this country from the Spanish mines, in South America. It has formerly been found in Scotland, and coined at the Scottish mint. Recently a considerable quantity has been found amongst the Wicklow Mountains, in Ireland, and some lumps have been obtained of considerable size, perfectly pure.

Gold, like platina, is not oxydated by exposure to the atmosphere, nor is it dissolved in any other than the nitro-muriatic, or oxygenated muriatic acid. This solution of gold yields yellow chrystals, which are a true muriate of gold.

Gold is precipitated from its solution by tin. If a plate of tin be immersed in a nitro-muriatic solution of gold, the oxide of gold forms on its surface a beautiful purple colour. This is the purple precipitate of Cassius, which is a valuable colour used by enamellers.

Alkaline sulphurets unite with gold, both in the dry and humid way. Many amusing experiments have been produced from the revivification of gold out of these combinations.

The ammoniacal oxide, or fulminating gold, is obtained from a solution of gold in nitro-muriatic acid, to which ammonia has been added. This produces a precipitate that weighs about a fourth more than the gold that was dissolved, which must be carefully washed and dryed on paper.

This oxide explodes with considerable violence, either by heat, pressure, or percussion. If a grain be exposed to a candle, on a knife point, it produces a loud detonation.

The explosion seems to arise from the decomposition of the ammonia, the hydrogen of which, united with the oxygen of the gold, condenses and forms water, restoring the gold to its metallic state, and setting free the nitrogen.

Silver is very malleable and ductile, but not so much so as gold. It is of a bright white when pure, and is about 10½ times heavier than water. It does not oxydate by exposure to the atmosphere, but frequently obtains a bluish or blackish appearance from its ready union with sulphur.

Silver will not oxydate in an ordinary degree of temperature. When exposed to violent heat it is converted into a vitrious oxide of an olive green colour. During the time that silver is exposed to an intense heat, it reflects the light so brilliantly that it seems to corruscate.

Silver dissolves both in the sulphuric and nitric acid; more particularly the latter; and when the silver is pure the fluid is colourless.

Muriatic acid will not act on silver alone, although it will take it out of its combination with the other acids.

When silver is dissolved in nitric acid it chrystallizes. These chrystals being collected, heated, and poured into moulds, form lunar caustic.

If a layer of dry nitrate of silver be laid upon a piece of burning charcoal, it throws out beautiful scintillations, leaving a plate of revived silver upon it.

Nitrate of silver is precipitated or thrown out of its combination by the alkalis. Copper precipitates silver from its solution in nitric acid. Nitrate of silver stains hair and other animal substances black. From this peculiar property it has been used, but without much success, in turning red or white hair black, or of a dark brown colour; but when applied to the hair on the head, it not only stains the hair, but the skin likewise, which produces a very unpleasant appearance; and as the stain is only superficial, the white hair soon springs up again, which produces a singular effect, one part being white, the other brown.

In some instances this experiment has been more effectual, but not more fortunate; for by applying the acid too strong, the hair and skin have been both burnt off together; yet there are Quacks nefarious enough to recommend this application, and I am sorry to add, some persons weak enough to be duped by them.

Silver unites with most of the metals. If quicksilver be poured into a bottle containing nitrate of silver, and be left undisturbed for some time, the silver will precipitate in an arborescent form, shooting in all directions, like the branches of a tree, from which it has been called arbor dianæ.

When silver has been precipitated from its solution in nitric acid, and the powder washed and dried, on putting it into liquid ammonia, it obtains a black appearance. If the ammonia be poured off, and the powder again dried, it forms the most violent of detonating substances, and is called fulminating silver. The greatest caution should be employed in using it, as it explodes by the slightest friction or pressure; so that it is even unsafe to pour it from the paper on which it has been dried into a bottle. Only very competent Chymists should attempt to prepare this powder.

The principle on which fulminating silver explodes is the same as that which has already been explained when treating of fulminating gold.

Mercury, or *Quicksilver*, is 13½ times heavier than water, and assumes a gasseous state at 600 degrees of Fahrenheit's. It becomes solid and malleable at 40 degrees below zero. That mercury might be frozen or rendered solid by the abstraction of its caloric, was first discovered by the Russian Academy, previous to which time it was generally considered to be a permanently fluid metal, as it was supposed to remain always fluid under the temperature of the atmosphere; but it is now known that in Kamschatka and other high latitudes, at particular seasons, the excess of cold is sufficient to freeze mercury in the open air.

The readiest artificial means of freezing mercury, is to introduce a small portion of quicksilver in a thin glass tube, into a mixture of muriate of lime and fresh fallen snow, which produces a temperature 40 degrees below zero, or 72 degrees below the freezing point of water, which, if the experiment be nicely conducted so as to exclude any accession of heat from surrounding bodies, will be just adequate to the effect.

Mercury dissolves in sulphuric and nitric acids. When nitrate of mercury is evaporated to dryness, it forms red precipitate, or the red oxide of mercury.

Muriatic acid will not dissolve mercury alone, although it combines with it by double chemical affinity. If sulphate of mercury be formed by dissolving it in sulphuric acid, on mixing it with common salt or muriate of soda, the quicksilver will unite with the muriatic acid of the salt, and form muriate of quicksilver, and the soda will combine with the sulphuric acid, forming sulphate of soda, or Glauber's salt. Muriate of mercury is called corrosive sublimate. If more mercury be added, so as to diminish the oxygenation, it is then called submuriate of mercury, or calomel.

The oxides of mercury may be reduced, or the metal revived, by heat only, which liberates the oxygen, and forms pure oxygen gas.

Mercury unites with sulphur, and forms two distinct compounds; one called red sulphuretted oxide of mercury, or cinnabar, of which vermillion is made: the other, black sulphuretted oxide of mercury, which is called Æthiop's mineral.

Mercury unites with gold, silver, tin, lead, and most other of the metals, forming with them a paste, or amalgam. If an amalgam of lead and bismuth be mixed or rubbed together, they possess the remarkable property of becoming fluid. From its strong disposition to amalgamate with gold and silver, mercury is used in working the gold and silver mines in Spanish America.

The earthy mass containing a portion of gold, is intimately mixed with quicksilver, and by this method the two metals exclusively combine; the heterogeneous earthy matter is then washed away by placing it in a current of water, which drives off the lighter bodies, leaving the amalgam of gold and mercury behind: These are separated by exposing the compound to an ardent heat, which volatilizes the quicksilver, leaving the gold pure. The mercurial vapour is collected and condensed in a proper receiver, and again rendered useful for a similar process.

Fulminating quicksilver is obtained by dissolving the metal, by the aid of heat, in nitric acid; when cold, the solution must be mixed with alcohol, and heat again applied, which precipitates a whitish powder. This powder, when carefully washed and dried, readily explodes, either by heat or friction. If a grain or two be twisted up in a piece of paper, and struck by a hammer on an anvil, it produces a loud detonation. If a small quantity be thrown into strong sulphuric acid, it likewise explodes, but this experiment is very dangerous.

Palladium, *Rhodium*, *Iridium*, and *Osmium*. The ore of platina has been fertile in new metals. The two first were discovered by Dr. Wollaston, and the other two by Mr. Tennant. After a laborious process, 4 grains of a black powder, called Rhodium, were obtained from 4000 grains of the ore of platina.

Palladium is of a duller white than platina. It is both malleable and ductile, and is obtained in greater quantity than rhodium.

Iridium is of a white colour, and is perfectly infusible by any means yet known.

Osmium is of a dark grey, or blue colour, and readily unites with mercury.

These metals, as well as some others that have been lately discovered, are interesting, and worthy of investigation in a scientific point of view; but it does not seem probable at present that they will ever be rendered generally useful.

Copper is malleable and ductile, and is about 8½ times heavier than water. When it is heated in contact with the atmosphere, its surface becomes oxydized, and in a violent state of ignition it burns with a green flame. Oxides of copper are reduced by carbon and hydrogen, which take up the oxygen, and restore them to the metallic state. Copper does not act upon water. If water be poured through a heated tube of copper, there is no decomposition effected.

Copper is readily decomposed by the nitric and acetic acids; but the muriatic and sulphuric acid must be in a boiling state to dissolve it.

When copper is dissolved in nitrous acid, it gives out an abundant quantity of nitrous gas, and a blue solution is produced which chrystallizes and forms a metallic salt, called nitrate of copper.

The solution of copper in muriatic acid produces chrystals of a grass-green colour, called muriate of copper.

When dissolved in sulphuric acid and chrystallized, blue vitriol or sulphate of copper is formed.

Copper easily unites with sulphur and forms a sulphuret; during the formation of this mass, a phosphorescent light is given out.

Acetate of copper or verdigris, is produced by the combination of the acetic acid with copper, either by corroding the surface of a plate of copper with vinegar, or more readily by dissolving an oxide of copper in it.

Tin has such affinity for oxides of copper, that if a moistened nitrate be twisted up in tin foil, it will take fire and burn with a green light.

A few drops of ammonia poured into a weak solution of acetate, nitrate, or sulphate of copper, will produce a beautiful blue colour, which may be instantly destroyed by adding a few drops of dilute acid.

As copper is very poisonous when it is received into the stomach, ammonia becomes highly useful as a test to ascertain the presence of dissolved copper. The beautiful green colour which pickles frequently possess, is derived from a solution of copper, either by boiling the vinegar in a copper vessel previous to its being poured on the vegetable, or by actually introducing a piece of copper into a tinned vessel. The copper is rapidly detected by pouring in a small quantity of ammonia, which will give the whole a blue colour, and this may be again changed by a few drops of dilute sulphuric acid.

Iron is not only one of the most useful metals, but it is likewise the most plentifully diffused by nature. It exists in the animal and vegetable, as well as in the mineral kingdom. It is hard, elastic, ductile, weldable, and malleable, having a specific gravity of about 7½. It very readily combines with oxygen, and decomposes air and water.

The oxides of iron have different colours according to the degree of oxydation. An inferior quantity of oxygen produces a dark or black colour. A greater quantity gives a brown, and a full state of oxydation has a red appearance.

Iron readily unites with carbon, and forms carburet of iron. It will likewise unite with carbonic acid, forming carbonated oxide of iron.

Steel is produced by the combination of iron and carbon. The diamond, which is pure carbon, has been dissolved and united with soft iron, converting it into steel by carbonization. The common mode of making steel is to surround bars of iron with charcoal in close vessels and expose them to a white heat, which produces a union between the iron and carbon.

Iron is acted upon by the generality of acids. If dilute sulphuric acid be poured upon iron, the metal is first oxidized by the decomposition of the water, and the oxide is then dissolved by the acid, which forms green chrystals, called sulphate of iron, or green vitriol.

When an infusion of nut-galls is mixed with a solution of sulphate of iron it produces common ink. This combination is obtained by the affinity of the gallic acid for the oxide of iron. Gum is added to the ink to keep the colour from precipitating, and a little spirit to preserve it from moulding and freezing.

A sympathetic ink is produced by writing with a solution of sulphate of iron, and when quite dry, washing it over with tincture of galls.

Common ink is decomposed by most of the acids. It is on this account that vegetable acids are employed in removing ink stains from linen. Dilute sulphuric acid will decompose the ink with more facility; but without great care the fabric of the linen may be easily destroyed. The best and safest fluid for removing stains of ink, wine, or vegetable juices, is the oxygenated muriatic acid.

The decomposition of ink produces an amusing chemical experiment. If an infusion of galls be poured into a solution of sulphate of iron, or green vitriol, it instantly produces ink;

but on adding a few drops of dilute sulphuric acid, it immediately becomes colourless. This decomposition arises from the superior affinity of the iron for the sulphuric acid, which takes it out of its combination with the gallic acid.

Writing is instantly effaced by washing it with dilute sulphuric acid, and without injury to the paper, if the acid be sufficiently diluted.

If a solution of prussiate of potash be mixed with a solution of sulphate of iron, a beautiful greenish blue precipitate is produced, which forms a good writing ink. Prussiate of potash is obtained by the combination of the prussic acid with potash, and prussic acid is formed by the decomposition of animal substances in a high temperature; particularly from blood and the horns and hoofs of animals.

If characters be written with prussiate of potash and washed with a solution of sulphate of iron, they immediately become visible, and of a blue colour.

Muriate of cobalt forms the most convenient sympathetic ink. When words are written with this fluid they are totally invisible, but appear of a beautiful green colour when they are presented to the fire. This colour disappears by breathing on the paper, or even by the absorption of moisture from the atmosphere, but is reproduced as soon as the paper is presented again to the fire.

Iron unites readily with sulphur, and forms sulphuret of iron. If a paste be made of sulphur and iron filings, moistened with water, on burying it in the ground, it soon begins to smoke and expand, and as it forces its way to the surface, bursts into a flame. This has been called an artificial volcano.

Plumbago, or black lead, is a carburet of iron. It is of a blackish blue colour, and is indestructable by heat without the admission of air. Plumbago dissolves in oxygenized muriatic acid, but the other acids have very little effect upon it.

Nickel is a silvery white malleable metal, 8 times the weight of water. It does not oxidize by exposure to the atmosphere. It unites with sulphur, but does not amalgamate with mercury. The nitric and nitro-muriatic acids dissolve it, and it is precipitated by the alkalis.

Nickel is acted upon by the magnet, with a force very little inferior to that of iron, and will receive a magnetic influence by being treated in the usual mode; but this is supposed to proceed from the iron with which the metal is almost inseparably united.

Tin is one of the lightest metals; its specific gravity being very little more than 7. It is very soft and ductile, and expands more than any other metal by heat.

Tin melts at a temperature of 410 degrees, and during its fusion the surface is soon covered with a grey oxide, which becomes white by exposure to the atmosphere. This is called Putty, and is used for polishing hard bodies. It is likewise mixed with glass to make white enamel.

What is usually called tin, is sheet iron covered with tin.

Mercury unites with tin. This forms the amalgam used for coating looking glasses.

The sulphuric, muriatic, and nitric acids dissolve tin; particularly the latter, which acts upon it with great violence.

A combination of tin and sulphur has a bright yellow colour, and is called aurum musivum.

If tin be heated with oxygenated muriate of potash, it produces an explosion. It likewise detonates when it is mixed with this salt and struck upon an anvil. Tin filings take fire when they are thrown into oxygenated muriatic acid gas.

Bronze and bell-metal are formed by the union of tin and copper, which is rendered more sonorous by the addition of a little iron. Tin is likewise used with other metals in forming specula for reflecting telescopes.

If a compound be formed of three parts tin, five bismuth, and two lead, it will melt in boiling water.

Tin is employed with zinc in forming an amalgam with mercury for exciting electrical machines. The proportion is generally one part tin, one zinc, and two mercury, which are united in a crucible by a gentle heat.

When tin is mixed with lead and antimony it forms pewter. It will likewise unite with the surfaces of iron and copper.

Lead is a very inelastic body, less tenacious and sonorous than any other metal. Its specific gravity is about $11\frac{1}{4}$, and it melts at a temperature of 540 degrees. In the first state of fusion it becomes covered with an imperfect oxide of a grey colour. As the heat increases the oxidation augments, until the surface becomes covered with a yellow mass, called Massicot. When this is cooled and freed from lead that is not oxidized, it is ground and again exposed to a moderate heat, which completes the oxygenation, and forms red lead.

Litharge is obtained by exposing fused lead to a violent degree of heat.

All these oxides of lead give back their oxygen by heat. If a small quantity of red lead be laid upon a piece of lighted charcoal, by the aid of the blow pipe, the oxygen will be driven off, and the lead revived. Or the metal may be obtained by heating it in a crucible with charcoal.

Lead, like copper, is very poisonous when it is received into the stomach; and although water will not combine with pure lead, yet it will dissolve a small portion of its oxide. It is on this account that water which has stood for some time in a leaden cistern cannot be considered healthful, particularly when it receives spring water, as the acids contained in it, unite with the surface of the lead, and form an oxide; this being dissolved, is diffused throughout the whole fluid.

The oxide of lead decomposes common salt. The muriatic acid unites with the oxide and leaves the soda.

All the acids combine with lead and its oxides. The acetous acid, or common vinegar, corrodes lead, and forms an imperfect oxide on its surface, which is called white lead. When this is dissolved in vinegar and chrystallized, it forms the acetate or sugar of lead. The oxides of lead are indispensable in glass making, for rendering it more transparent and less brittle. The oxides of lead boiled with oils harden them and make them dry much sooner.

The acetate of lead is sometimes employed to soften the taste and alter the appearance of new wine. This practice is highly pernicious, and deserves the severest reprobation. The adulteration may be discovered in the following manner:

Equal parts of oyster shells and crude sulphur are to be kept in a white heat for fifteen minutes, and when cold, this mass is to be mixed with an equal quantity of acidulous tartrite of potash, and boiled in a glass vessel for an hour; after which it is to be decanted and put into ounce bottles, well corked, for use. When this fluid is poured into wine that contains the least portion of the acetate of lead, it precipitates the metal in the form of a metallic dark coloured sediment.

Characters written with a solution of acetate of lead, become visible by exposing them to sulphuretted hydrogen gas, which decomposes the oxide.

Zinc has a white appearance, something between that of lead and silver. Its specific gravity is rather more than 7. When zinc is in the first state of fusion it is covered with a grey oxide, but when it is strongly heated it inflames and sublimes into white flocks, forming a complete oxide.

From the great affinity of zinc for oxygen it decomposes water even at the temperature of the atmosphere; but when heated the decomposition is much more rapid.

If red precipitate (the red oxide of mercury,) be heated with filings of zinc, it inflames, from the rapidity with which the oxygen is obtained from the mercury by the zinc.

Zinc decomposes acids; when introduced into concentrated nitric acid, nitrous gas is given out. If the acid be diluted it produces nitrous oxide, which is a state of inferior oxydation. Dilute sulphuric or muriatic acid acting on this metal evolves hydrogen from the water.

When zinc is dissolved in pure sulphuric acid, it shoots into regular chrystals, called sulphate of zinc, or white vitriol.

Zinc boiled with the alkalis is partially acted upon by them, and the product is of a yellow colour.

Zinc detonates with nitrate of potash. When three parts nitrate of potash and one of zinc are set on fire, they burn with great splendour, and throw out beautiful sparks, which burst as they are projected; this compound is much employed in making artificial fire-works.

Zinc united with copper, forms brass, with tin and copper, bronze.

Lead is thrown out of its combination with the acids by zinc. If a piece of zinc be suspended in a solution of acetate of lead, the lead will unite with the zinc, and form beautiful chrystallized ramifications, which have an arborescent appearance.

Bismuth is a very fusible, brittle, white metal, having a specific gravity, 10 times greater than water. It does not oxydate by mere exposure to the atmosphere. When it is placed in a moderate heat the surface is covered with a grey oxide; but in a red heat it burns with a blue flame, and sublimes into yellowish smoke which is condensible, and forms a true oxide of bismuth: this is very fusible, and may be converted into a yellow transparent glass, by heat.

Bismuth not having great affinity for oxygen, does not decompose water. It combines with sulphur by fusion, and forms a sulphuret.

The acids act upon this metal and produce sulphate, muriate, and nitrate of bismuth.

Characters written with a solution of bismuth in acetic acid, become blackened and legible by exposing them to sulphuretted hydrogen gas. Bismuth precipitated from its solutions, has been used as a white paint; but this soon loses its colour from the action of sulphuretted hydrogen. It combines with gold, silver, copper, and tin, and forms an amalgam with mercury.

Antimony is combined with sulphur in its native state: when separated, it forms a silvery white brittle metal, of scaly texture, with a specific gravity of about 7.

The ordinary state of the atmosphere produces very little effect upon the surface of this metal; but when it is fused it emits white condensible fumes, which are a true oxide, and were formerly called flowers of antimony.

When copper, tin, silver, or iron, are fused with the native sulphuret of antimony, the sulphur is driven off, and the antimony combines with the metals.

Alkalis combine with the sulphuret, and form alkaline sulphurets, or liver of antimony. Almost all the acids dissolve and combine with this metal. The nitric acid acts most violently upon it. The nitro-muriatic readily separates it from its original combination with sulphur.

Dr. Pearson concludes that Dr. James's

celebrated powder is formed of phosphoric acid, and a double basis of lime and antimony.

The acid of tartar forms with the grey oxide of antimony, the antimoniated tartrite of potash, well known by the name of emetic tartar.

The white oxide of antimony combined with the white oxide of lead and muriate of ammonia, in a red heat, forms the brilliant pigment, called Naples yellow.

Tellurium is of recent discovery, and is found in some ores of gold: it readily combines with sulphur and quicksilver, and has a greyish appearance, possessing considerable metallic splendour. Its specific gravity is not more than 6 times that of water. Tellurium is very brittle, and fusible at a low temperature. It is neither very ductile nor malleable, and when oxidized by heat, burns with a blue flame. The nitric and nitro-muriatic acids dissolve it, and it is readily precipitated from its solution by water, which throws it down in a white powder. Zinc, tin, or iron will likewise take it out of its combination with acids.

The oxides of this metal are easily reduced by exposing them to an inferior temperature upon a piece of charcoal.

Arsenic is found united with various ores, and is separated from them by calcination and sublimation; it then forms an oxide of arsenic, or arsenious acid, which is the white powder sold under the name of arsenic. This powder is deoxygenated by mixing it with black flux, and exposing it to a strong heat in a crucible. The metal which is thus obtained soon loses its metallic brilliancy and becomes oxydated by mere exposure to the atmosphere. The metal is easily fused, and is volatilized at 356 degrees of Fahrenheit. It burns with a blue flame and white smoke; and what most particularly characterizes this deadly poison, is the very acrid taste and strong smell, like garlic, which it produces when thrown on red hot iron.

Arsenic inflames in oxygenated muriatic acid. Mixed with oxygenated muriate of potash, it produces a detonating powder, which is much more rapid in its effects than gunpowder. The mixture requires considerable precaution; for if too much friction be employed the compound will take fire and explode. If a long train be formed of this powder, on igniting it at one end, the flash spreads almost instantaneously to the other extremity.

Cobalt in its pure metallic state is white, reflecting rather a pinkish appearance. In its native state it exists in combination with arsenic, and when it is roasted in proper furnaces the arsenic is driven off, and what remains is called zaffre. By fusing the zaffre with black flux, the cobalt is obtained in its metallic state, which has a specific gravity of about 7¾. If zaffre be fused with sand and potash, it forms a hard blue transparent mass, called smalt. This is pounded and sifted to mix with glass to give the latter a blue colour.

Cobalt tarnishes by exposure to the air, but does not unite with the oxygen of the atmosphere. When it is intensely heated, it burns with a red flame, and the oxide is of a dark blue colour.

It dissolves in nitric and muriatic acids; in the latter it forms a curious sympathetic ink. When characters are written with this fluid they are totally invisible, but if the paper be held to the fire they instantly appear of a beautiful green colour, and again become invisible by the absorption of moisture from the breath or atmosphere. These characters will re-appear whenever the paper is presented again to the fire.

Manganese is a metallic oxide, which is very plentifully diffused. It has different appearances according to its degrees of oxydation. That which is imperfectly oxygenated has a blackish brown colour; but when the oxide is complete it becomes of a shining black. From the great affinity of manganese for oxygen, it holds it so redundantly that oxygen gas may be obtained from it at a low heat; but to free the metal totally from its combination with oxygen, it requires the highest temperature that can be produced. The metal is of a dusky white colour, with a specific gravity of about 7. It soon loses its metallic state, and is again converted into an oxide by exposure even at the common temperature of the atmosphere.

In an imperfect state of oxydation, manganese is acted upon by every acid; but when it is a complete oxide, the acids have no effect upon it. This singular circumstance arises from the great avidity of manganese for oxygen. In an imperfect state of oxydation it seizes upon the oxygen of the acid, and dissolves; but when saturated with oxygen it has no such affinity, and therefore remains unchanged.

Manganese is used in considerable quantities in the chemical laboratory for a variety of purposes where oxygen is required. Oxygen gas for chemical experiments is generally obtained from manganese by exposing it in an iron bottle to a red heat. The portion of oxygen which is slightly held, unites with the caloric, and forms oxygen gas, and this passes through a tube connected with the bottle into a proper receiver to be retained for use. After the manganese has thus lost a part of its oxygen, it becomes of a lighter colour; but if it be exposed to the air for some time, it will resume its blackness, its oxygen being restored by the atmosphere.

Oxygen gas is more readily obtained from manganese by pouring a quantity of sulphuric acid upon it, sufficient to form it into a kind of paste, and afterwards employing a gentle heat.

If one part manganese, and three parts nitrate of potash be put into a red-hot crucible, the salt becomes decomposed, and a green friable powder is produced, which is an alkaline oxide of manganese. This mass has the singular property of exhibiting different colours according to the quantity of water that may be added to it. A small quantity gives it a green appearance, a little more produces a blue, still more, a light purple, and a further addition communicates a beautiful dark purple colour.

Chrome is a metallic substance, found in an oxygenized state in the red lead ore of Siberia. When reduced to its metallic form it is brittle and very infusible. This metal is capable of 3 degrees of oxidizement. In the first it is green; in the second brown, and in the third state it forms the chromic acid, which is a bright red, and contains about two-thirds of its weight of oxygen.

The green colour of the emerald is supposed to be produced by chrome in its first state of oxidizement, and the red colour of the ruby from its last state.

When chrome is dissolved in nitric acid it unites with the alkalis. These chromic salts precipitate solutions of some of the metals of beautiful colours. Lead, in solution, is precipitated of a bright yellow; mercury of a cinnabar red, and silver of a carmine red.

Molybdena is found united with sulphur. This ore has a very metallic lustre, and marks paper much like plumbago.

The nitric and oxygenized muriatic acids are the only acids that act upon molybdena. It is capable of 4 degrees of oxidizement. The first produces a black, the second a blue, the third a green, and the fourth is a yellow oxide. The molybdenic acid combines with alkalis and earths.

Uranium. The oxide of this metal is found combined with sulphur, which may be separated by fire. The ore is then to be dissolved in nitro-muriatic acid, which will throw down an orange coloured precipitate. This, when exposed to an intense heat, produces uranium in its metallic state.

Tungsten is obtained from the tungstic acid, which is found united with calcareous earth, forming a mineral, called wolfram. Tungsten is so difficult of fusion that few experiments have been made on it in its metallic state.

The tungstic acid is easily obtained from its combinations, and readily unites with earths and metals. With sulphuric acid it forms a blue, and with nitric and muriatic acid, a yellow oxide. It likewise combines with sulphur, and forms a black chrystallized mass.

The remaining metals are *Titanium*, *Columbium*, *Tantalium*, and *Cerium*. These are called refractory metals; inasmuch as they cannot be obtained in their pure metallic state. Like the two or three last noticed metals, they are interesting only to the scientific enquirer, their properties not having hitherto been employed in the arts.

Vegetable Bodies.

THE vegetable world forms so beautiful, extensive, and useful a part of creation, that it necessarily arrests our particular attention. Although we cannot suppose that all the phenomena of vegetable life are exclusively the result of chemical processes, yet so many effects are evidently produced by the chemical energies of nature in all her productions, that the investigations of chemists in this department promise not only ample and curious discoveries, but also the most useful information, both in a commercial and agricultural point of view. By analyzing various soils, and the secretions of plants, the best modes of culture may be ascertained on scientific principles, and the physiology of vegetation be more satisfactorily understood.

Vegetables hold the next rank to animals, and whilst we pass from the sensitive to the insensitive state of existence, or from animals to plants, we are struck with the general similitude of the structure and functions of each. The vital operations of the two states have indeed such a manifest resemblance, that they can scarcely pass unnoticed by the most superficial observer. We all witness the birth, development, growth, and decay of plants, divided, as in animals, into stages which regularly succeed each other. The seed gives birth to the young plant; at a certain age the plant fructifies and perpetuates its species; for a period it remains flourishing and healthy in this adult state, when it ceases to grow, and we see the energies of nature gradually decaying, until enfeebled by age, different parts lose their functions, and death ensues.

The growth and secretions of plants are effected as in animals, by vessels of different organization, which are abundantly distributed throughout their substance. The most conspicuous are the common or sap vessels, the proper vessels, air vessels, utricles and vessicles.

The *common* or *sap vessels* are cappillary tubes, which occupy a large portion of the vegetable body, and convey the sap through the main trunk to the extremities of the branches; these are analogous to the blood vessels of the animal system.

The *proper vessels* are those which secrete fluids proper or peculiar to different vegetables. These vessels are generally found connected with the under cortical layers, and different coloured fluids may be seen exuding from them in a transverse section of the plant, totally distinct from the sap which springs from the mouths of its own vessels that are more particularly distributed through the ligneous part.

The *air vessels* are very small, and often transparent; they are twisted into a spiral form, and run in the interstices between the sap vessels.

The *utricular texture* is composed of small irregular sacks, which are soft and full of a thick fluid. These are combined in the pith of the plant, and appear to be secreting organs which receive the sap from the common vessels, and prepare it for, and transmit it to, the proper vessels, where it gives the distinctive character to the vegetable.

The *vessicular texture* is only an expansion of the utricular; this proceeds horizontally from the centre, and passes through the meshes that separate the common vessels, until it spreads itself on the cortical layer beneath the outer bark, connecting the utricles with the proper vessels.

How secretion is effected either in the animal or vegetable body, is a point that has not yet been ascertained. We are sensible that it is an operation of nature totally different from all others that we are acquainted with; nor can it be resolved on any chemical principal which we at present understand. Different vegetables grow on the same soil, under the same circumstances, yet some will be bland and nutritious, others acrimonious and unwholesome. A similar cause for wonder appears in the animal world. Two creatures composed of the same elements and fed upon the same food, will form secretions equally different; the one, perhaps, the most odoriferous effluvia, the other the most disgusting fœtor.

Vegetables are also supplied with appropriate organs for absorption and excretion. The filaments of roots and the pores of the leaves are the principal organs of absorption. The absorbent vessels may be demonstrated by immersing these parts in coloured fluids, by which the vessels will be filled and tinged. A familiar and striking instance of the absorption of vegetables is the sudden effect which water produces in restoring a drooping plant when poured upon the dry earth that encloses its roots. It is generally admitted that the sap not only circulates upwards through the trunk and branches of plants, but that it likewise returns or descends under the bark, and thus produces a continued circulation. It is certain that if the bark be cut by a double incision, in a horizontal direction round a branch, and the intervening ring of bark be removed, that the upper edge of the wound will descend and approach the lower edge, which will remain stationary. Now as the newly formed bark is doubtlessly deposited by the sap, this experiment seems to be a satisfactory proof of a descending circulation.

The absorbed fluids during their circulation through the different vessels of the plant, become changed and modified by the processes of secretion. Some of these secreted fluids are deposited to increase the bulk of the vegetable; other portions to form its gum, resin, aroma, &c. What remains, being either redundant or unfit for these purposes, is excreted from its leaves in a gasseous or fluid state.

It is equally important to the health of vegetables, as to that of animals, that the mouths of these excreting organs should be kept free from obstruction. It is on this account that careful and attentive gardeners almost daily wash the leaves of valuable plants with a sponge.

In the whole of the interior structure and functions of vegetables, there is so great an analogy to the animal system, that we cannot sufficiently admire the general relations of nature in her operations. To preserve and support vegetable life, the food is principally taken up by the absorbents of the root, and diffused by those vessels throughout the system; undergoing various changes, until it is returned by another set of vessels, which deposit what remains fit for secretion, and exhale the remainder.

In the animal system the stomach is the receptacle of the food. The absorbent vessels take up a portion of the digested aliment, and pour it into the blood vessels; these circulate the fluid through every part of the body; the various organs form their secretions from it, and the waste and wants of the animal œconomy being supplied, the redundant part is chiefly exhaled from the surface of the skin.

Air, water, nutriment, light, heat, and electricity are essential to animal life, and we shall find in the continuation of this subject that the whole of these are equally indispensable for the support of vegetable existence. Even motion is not entirely denied to plants. Some species fold up their leaves spontaneously when touched by irritating substances. Others present their expanded flowers towards the sun during the whole of his diurnal progress. Flowers placed in a room will almost invariably turn towards the window; and if a plant be placed under a box the branches will soon wind their way through some outlet, to obtain the important influence of light and air. The propagation of plants is also discovered to be analogous to that of animals; but we shall limit our present subject to what is known of the chemistry of vegetation.

Light is essentially necessary to almost all vegetables, although we do not understand how its effects are produced. Let a plant have all the advantages of air, heat, and water, yet be deprived of light, it will soon lose its beautiful verdure, become of a sickly white, and speedily die. But if instead of solar light, that of lamps be substituted, its existence will be greatly prolonged. Some plants under such circumstances have even propagated their species.

It is difficult to ascertain whether these effects arise from the actual combination of light with the plant, or from its influence in favouring the decomposition of air, or other fluids. From the known changes produced by the immediate agency of light on many mineral and vegetable solutions, we are inclined to believe that the actual combination of light effects these important changes.

Between the tropics where the power and duration of light is greatest, the colours of plants are most vivid and various: approaching the gloomy polar regions, the beauties of the vegetable world gradually decline.

The blanching of endive, celery, and lettuce, &c. is effected by excluding light. The earth is heaped up about the plant, or the leaves are tied, so as to prevent the combination of light, and the healthful green disappears.

The free access of *atmospherical air* is essential to vegetation. If a plant be put in a glass case, with all the advantages of light, heat, and water, but without air, it will soon die.

If a vegetable be confined for some time in a limited portion of atmospherical air, on examining the air, it will be found that a principal part of its oxygen has disappeared, which must either have entered directly into combination with the plant, or else have united with the carbon of the earth in which it grew, and have formed carbonic acid. Carbon is found to be of the greatest importance in preserving and supporting vegetable life. Nitrogen and hydrogen gasses are fatal to plants as well as to animals; but carbonic acid gas, in which animals expire, gives additional energy to the vital functions of vegetables.

Ingenhouz supposes that the leaves decompose this gas, and that the fixed carbon becomes one of the elements of the plant.

Water contributes so much to the support of plants, that it may almost be said to constitute them. If a portion of well dried earth be weighed, and a small plant be placed in it, by regularly watering it, its bulk will increase, and in course of time, it will obtain a considerable magnitude. Take out the plant, and on drying, and weighing the earth, it will be found to have lost very little of its original weight, although the plant has increased, perhaps an hundred fold. Then from what has this increase been produced?

Certainly from the water and the surrounding atmosphere.

Dr. Ingenhouz having observed that leaves immersed in water and exposed to the sun, emitted oxygen gas, was led to suppose that water is decomposed in the vessels of vegetables, and particularly in those which are distributed through the leaves. He imagined that this decomposition was promoted by the agency of light; and that the hydrogen which was separated from the oxygen of the water, formed oils, gums, resins, and a considerable portion of the ligneous part of the plant. Oxygen, the other portion of the water, he supposed, was not only employed in forming acids and saccharine matter in the vegetable, but that there was likewise a super-abundant quantity given out from the surface of the leaves, in the character of gas; and that by this mode nature had provided for supplying the prodigious consumption of this important portion of the atmosphere, daily effected by combustion and respiration.

This hypothesis seems to unfold a system of great beauty and wisdom. That an immense quantity of oxygen gas is constantly decomposed, is sufficiently certain; and yet in the closest parts of the most populous cities, we do not find that the air has suffered any diminution of its oxygen: this supply must be produced by some extensive means; and there seems to be nothing more adequate to this purpose than the immense surface of vegetation.

Although light, air, and water are of such great importance to vegetation, they do not furnish the whole of the principles necessary for fertility: the vegetable body must have further sustenance.

If a plant be placed in sand, in a favourable situation, and regularly watered, it will vegetate for a time; but its fragrance will be faint, its fruit insipid, and it will at length become sickly and die. Water alone is not sufficient for its support; it wants additional food.

The agriculturist is well aware that the earth becomes exhausted by her productions, and that the soil must either lie dormant to recruit its exhausted powers, or be supplied with manure.

The ordinary procedure of nature seems to point out the necessity of this supply. The fallen leaves and dead vegetable matter putrify during winter, and then form, by a natural process, the necessary manure.

A knowledge of the chemical constitution of vegetables, will best explain the use of composts and manure. Oxygen, hydrogen, and carbon are the general elements of vegetables. Sulphur, lime, silex, and potash, occur in some instances; but the first three are universal, therefore it is obvious these are all that vegetables want for their support; and these are contained in manure. We are very sensible that manure contains free hydrogen; not only from the smell, but from the inflammability of the gas which is perpetually escaping from the surface when it is in a high state of putrifaction. The carbon is visible, occasioning its usual black appearance, and the carbonic acid gas that escapes and may be easily detected, is a certain proof of the existence of oxygen.

The fertilizing quality of manures, probably arises chiefly from the quantity of carbonic acid that is produced. Water is the vehicle which holds it in solution, and carries it to the absorbent roots of the vegetables. The carbon thus taken up constitutes one portion of the plant, and the other two (the oxygen and hydrogen,) may be derived from the décomposition of the water itself.

The products of vegetation, in a chemical view, are very numerous; some are universal, and belong to all vegetables: others are peculiar, and appertain but to a few.

Mucilage, in its solid state, forms gum, which is soluble in water, but not in alcohol. It is transparent, brittle, and inodourous; it dissolves in pure alkalis, and is precipitated by acids.

Mucilage forms the basis of the juice of plants, and likewise constitutes a considerable portion of the seed. It is converted by heat into a coaly substance, without inflaming; and during this change, it gives out carbonic acid gas. It appears to be composed of hydrogen and carbon, with a very small portion of oxygen. When mucilage is diluted with water, it soon passes into the acetous fermentation, from which vinegar or the acetic acid may be obtained by distillation.

Fecula of vegetables seems to vary very little from mucilage. To obtain the fecula, the plant is bruised and diffused in water, in which the feculent part subsides, and by evaporating, the water may be obtained pure. In this manner starch, potatoe flour, sago, arrow root, &c. are obtained from their respective vegetables.

Vegetable Gluten is obtained from flour, by forming a paste, and washing it under water until it remains clear. The substance which is thus obtained is elastic and tenacious, and becomes more and more adhesive as it dries. It soon putrifies when exposed to the air, and if placed on hot coals, it curls up and emits a strong animal smell.

Sugar is obtained from a great number of vegetables, amongst which are maple, carrots, corn, beet, parsnips, turnips, grapes, and various other fruits: but the sugar-cane affords the greatest quantity. The juice is first squeezed from the cane, and then boiled until it has obtained the consistence of syrup: this is again boiled, with the addition of alum and lime, until its consistence is greatly increased. The treacle, or molasses, is then drained off, and when cool it forms a solid mass of imperfect chrystals. In this state the sugar is imported into this country, where it is again refined to form loaf or lump sugar, by boiling the raw sugar with lime water to neutralize the acid; after which, it forms harder and more perfect chrystals. Bullocks blood is generally added; the albumen of which, coagulating by heat, takes up most of the impurities that are contained in the mass. If the refined fluid be left to chrystallize freely, without being poured into those conical moulds which shape the loaves, it forms those large regular chrystals, called sugar-candy.

Sugar is composed of 64 parts oxygen, 28 carbon, and 8 hydrogen. It is very soluble either in water or alcohol; is very inflammable, and detonates with oxygenated muriate of potash. If two pieces of sugar be rubbed together in the dark, they produce an electrical light, and have likewise an electrical smell. By the vinous and acetous fermentation, sugar forms alcohol and acetous acid.

Vegetable oils are of two kinds, fixed and volatile.

The *fixed oils* are obtained by pressure from seeds or kernels. Olive, almond, and linseed oil, are of this description. When no heat is employed, they are called cold drawn oils.

Both volatile and fixed oils are composed of oxygen, hydrogen, and carbon. The volatile have much more hydrogen than the fixed oils. Oxygen readily combines with oil in two ways: when incorporated with the oil itself, it converts it into what painters call a *drying oil;* but when united with the mucilage of the oil, it produces rancidity. This mucilagenous part may be separated from the oil by agitating it with water, which will take it up: after this operation the oil will keep sweet for a considerable time.

To make *drying oil*, it is boiled with an oxide of lead; the oxygen of which enters into direct combination with the oil.

Oils likewise combine with alkalis and the alkaline earths. Soap is produced by boiling oil or tallow with alkali, in water for a considitime. The best white soap is composed of tallow, potash, and soda. In the mottled soap less pure tallow is used; and yellow soap is formed by adding resin to the alkali and fat. The common soft soap is made from fish oil and the ley of potash, with a small portion of tallow mixed with it, which forms the white spots.

Lamp black is obtained by burning oil in a close place where there is not a sufficient access of oxygen to produce the entire combustion of the oil; it is deposited like soot, and scraped off from the receptacles in which it is collected for sale.

Fixed oil dissolves sulphur, and forms what is called balsam of sulphur.

Volatile or *essential oils* are contained in vegetable bodies; they have a very penetrating smell, and a pungent taste; they unite with alcohol, and do not readily combine with alkalis.

Volatile oils are evaporated by a gentle heat, and thicken by exposure to the atmosphere so as to obtain a resinous state. Water will dissolve a small quantity of volatile oil, which communicates to it the peculiar odour of the vegetable from which it has been obtained. Thus, peppermint, lavender, or rose water, are obtained by simple distillation. The lavender water of the shops is generally formed by dissolving a small portion of the essential oil in alcohol, and then mingling it with water.

Camphor is a vegetable production, and has similar properties to the essential oils.

Resins are formed by the exudation of juices from the wounded bark of particular plants, which become concrete by their union with the oxygen of the atmosphere. Resins are highly inflammable, and during inflammation produce a considerable quantity of soot. They dissolve in alcohol or æther, but not in water. Varnishes are made by the solution of different resinous substances in alcohol, or spirit of turpentine.

Turpentine is obtained by exudation from the fir-tree, and appears to be composed of resin and volatile oil.

Tar is a vegetable production, and is likewise obtained from the fir-tree, and also from a particular kind of coal. Tar in its concrete state, is called pitch.

Tan is found in a variety of vegetables, particularly in the willow, chesnut, hazel, and ash; but it exists most abundantly in the bark of the oak: it may be likewise obtained from nut-galls, tea, and red port.

Tan unites with the gelatin of hides in the operation of tanning, and forms the substance, called leather.

Tan may be separated from the bark in the following manner: To a cold infusion of oak bark add a solution of muriate of tin, which will precipitate the tan, together with the oxide of tin. The tin may then be separated from the tan by sulphuretted hydrogen, which will combine with the former, and leave the latter pure, of a light-brown colour.

On account of the great utility of tan, and the difficulty of procuring it in sufficient quantity, its peculiar properties have been particularly examined by Mr. Hatchet, with a view to discover some more ready means of obtaining it. He has produced it from a variety of bodies, but not in sufficient quantities to render his interesting researches of much public utility.

When tan is combined with alkali, it has great affinity for the metallic oxides.

Caoutchouc, or *Indian Rubber*, as it is generally called, is a vegetable production: it exudes from different plants in India: when it is first obtained, it has a white appearance, but becomes black by drying. This gum dissolves in æther, and forms an excellent varnish.

FERMENTATION. This is a process which changes the combinations of the elements of vegetables, but it probably never takes place whilst life exists in them.

Oxygen appears to be the great agent of fermentation.

There are three states of vegetable fermentation, the vinous, acetous, and putrid. Fourcroy considers the making of malt to be a fermentative process. The object of the process, called malting, is to convert grain, from its insipid state, into a highly saccharine substance. Barley is most frequently used for this purpose. The first step is to soak it in water for some hours, after which it is laid in a heap to sprout. When it has sprouted about two thirds of the length of the grain, further germination is stopped, either by exposing it in thin layers to a current of air, or by the more usual mode of drying it by heat.

In this operation the water imbibed by the grain is decomposed by the process of vegetation; and it is a material point in the art of malting, to know precisely when this process ought to be stopped; if it be carried too far the substance of the grain will be too much wasted; and if not far enough, the seed will not be sufficiently oxydized; consequently, when dry, it will be deficient in saccharine matter.

The art of brewing consists in separating the saccharine matter from the other parts of the oxygenized grain or malt; this is effected by pouring hot water upon the malt, which dissolves the sugar and a portion of mucilage.

After the hops are added, and the fluid is cooled to about 70 degrees of Fahrenheit, a proper quantity of yeast is mingled with it, and the vinous fermentation commences: the liquor becomes turbid, an increase of temperature takes place, and an internal motion is observable throughout the whole. During this process a most abundant quantity of carbonic acid gas is disengaged; a portion of carbon also combines with hydrogen and oxygen, and forms the ardent, inflammable and intoxicating fluid, called alcohol; the quantity of which constitutes what is called the *strength* of the beer, and depends on the quantity of malt, or saccharine matter, that has been employed.

Wine, cider, perry, and all other intoxicating liquors are products of the vinous fermentation: the spirituous part in all depends on the quantity of saccharine matter, and the peculiar flavour on the volatile oils, and essential principle of the vegetable from which each is derived.

Foreign grapes supply, naturally, a sufficient quantity of saccharine substance, so that the whole process of making wine from them consists in expressing the juice, and afterwards fermenting it. English wines require an added quantity of sugar, inasmuch as the fruit from which they are made is deficient in the saccharine principle; so that without this addition there could not be a sufficient quantity of alcohol formed to prevent the wine from spoiling or becoming sour.

Light and heat are necessary agents for the production of the vegetable oxide, sugar; therefore ripe fruit contains more sugar than that which is green. But in this climate fruit never ripens to such perfection as to preclude the necessity of an additional supply; it is therefore recommended to employ unripe fruit, and to make up for the natural deficiency by supplying manufactured sugar; for during the oxydating or ripening process, the volatile effluvia or essential flavour of the vegetable, escapes. Those who have tasted English wine made from unripe gooseberries, are well aware that it is much superior to that made from the full ripe fruit. In making sweet cider the apples are suffered to lie together on heaps for a considerable length of time, that the further oxydation of the vegetable acids may be effected. But we are sensible from the taste of such cider, that this sweetness is obtained at the expence of the fine flavour of the vegetable.

Distillation is the method of separating the spirituous from the aqueous part of fluids that have undergone the vinous fermentation. The alcohol thus obtained, is called brandy, rum, gin, arrack, or whiskey, &c. according to the vegetable from which the saccharine matter has been derived.

If the fermented fluid be put into a proper apparatus, called a still, and heat applied, the spirituous, or alcoholic part, will be converted into vapour, at the temperature of 176 degrees, which is 36 lower than that at which water takes the form of steam; consequently, if the temperature of 176 degrees be equably kept up, the whole of the alcohol may be driven off before the water boils.

As the spirituous vapour rises, it is compelled, by the structure of the still, to pass through a long spiral tube, which is immersed in a vessel of cold water. During this transmission it loses the heat by which it obtained its gasseous state, and is condensed into a fluid, specifically lighter than water, in the proportion of about 8 to 10.

Alcohol combines chemically with water, and during the union, heat is evolved. If strong rum be poured into water of the same temperature, the heat will be increased 10 or 12 degrees, and a diminution of bulk will take place according to the quantity of heat given out. For instance, if 30 gallons of water be added to 100 gallons of rum, in the state in which it is imported, the whole will not amount to more than 127 gallons; thus there will be a diminution of the bulk of the whole, equal to 3 gallons.

Carbonic acid and water are produced by the combustion of alcohol; and the weight of these results is greater than the weight of the alcohol consumed, by the weight of the oxygen which has been taken from the atmosphere during the combustion.

Alcohol has never been frozen by the greatest degree of artificial cold hitherto produced; although æther, which is formed from alcohol, and is specifically lighter, has been chrystallized at a very low temperature.

The *acetous fermentation*, or that which produces vinegar, takes place in liquors that have undergone the vinous, by exposing them to oxygen gas, or to the atmosphere, at a greater temperature than 70 degrees, and less than 90.

When this fermentation commences, the fluid soon becomes warm, and a ropy substance appears in it. It emits a disagreeable odour, and in a few days obtains an acid taste, which increases until the whole is converted into vinegar or acetous acid. The acetic acid is produced by further oxidizement, or by getting quit of the aqueous fluid that is contained in the acetous; which is easily effected by exposing vinegar to a sharp frost, which freezes the water, and leaves the acetic acid in a fluid state.

To produce the vinous fermentation, it is not necessary to expose the surface of the fluid to the atmosphere; but for the acetous, oxygen is indispensable, and must be supplied, either from the atmosphere, or otherwise. For it is by the union of oxygen that the alcoholic part of the fluid is decomposed, loses its intoxicating power, and is converted into vinegar.

Vinegar-making, on a large scale, is generally carried on in summer, that the increased temperature of the atmosphere may favour the fermentation. The barrels which contain the fermenting fluid are not quite filled, that the surface of the liquor exposed to the oxygen of the atmosphere, may be greater.

The white ropy matter in vinegar, which is called *mother*, when thrown into vinous liquors, promotes the acetous fermentation, as yeast excites the vinous.

In an advanced state of the acetous fermentation, a portion of vinegar may be drawn off from the vessel, and an equal quantity of vinous fluid added; this very soon will become equally oxidized, and another portion may be taken out: in this manner a continued supply may be obtained from the same barrel.

The acetous acid unites with alkalis, earths, and metals, and produces a variety of salts.

The surface of lead is corroded by the fumes of hot vinegar; hence a sub-acetate, called white lead. When this is dissolved in distilled vinegar and chrystallized, it constitutes acetate, or sugar of lead.

If the surface of copper be exposed to vinegar, a beautiful green oxide of copper is produced, called verdigris; when this is scraped off and dissolved in vinegar, it chrystallizes and forms a salt, called acetate of copper.

The *putrid fermentation* of vegetables produces other combinations. Heat and water are essential in this process. When a quantity of green vegetable matter is heaped together, the colour soon changes; an increase of heat is produced in the interior of the mass, and decomposition takes place. The constituent elements, oxygen, hydrogen, and carbon enter into new unions. A portion of the hydrogen unites with the oxygen, and forms water, or aqueous vapour. Another part combines with carbon, and forms carburetted hydrogen gas; and in a few vegetables where nitrogen resides, the hydrogen will unite with that element, and form ammonia. The greater part of the carbon is employed with the oxygen in forming carbonic acid, the principal food of vegetables. The grosser parts mix together, become more solid, and ultimately form a brown mass of vegetable mould; returning again to the earth that portion of matter which had been employed in the composition of the vegetable.

The putrefactive process of animal matter is very similar to that of vegetables; but as there is a greater variety of elements, a greater number of combinations take place. In both instances, however, the wisdom of creation is equally admirable. So perfect is nature that nothing is lost or rendered useless.

Æther is obtained by the combination of alcohol, either with sulphuric, muriatic, or nitric acid. Æther evaporates rapidly when exposed to the atmosphere; and it boils at the temperature of 98 degrees. In passing from its fluid to its gasseous state, it takes up such an abundant quantity of caloric, that water may be frozen in a thin glass tube, by wrapping it round with cotton and dipping it in æther. If an animal were washed with æther, even under a meridian sun, it would soon perish with cold.

Æther burns rapidly with a bright flame. It is very sparingly soluble in water; but combines with essential oils and resins. Its specific gravity to water is as 7½ to 10. It freezes at 46 degrees below zero; which is 6 degrees lower than that point at which quicksilver is rendered solid.

The *colouring matter* of vegetable bodies is of great importance in the art of dying.

The colouring principle has been divided into four states of combination. In the first, it is united with the extractive principle, as in logwood and cochineal, from which the colouring matter is obtained merely by infusion in water.

Some gummy substances likewise contain colouring matter, from which it may be obtained by infusion in the same manner. Colour is also found in the farina or fecula of plants, from which it may be readily obtained by sulphuric acid. In the fourth state it is united with resins, from which it is separated by dissolving the substance in alcohol or alkali.

The art of dying consists in transferring the colouring matter from the body in which it resides, into some other.

Particular colours have such affinity for the substance in which they are to be incorporated, that they readily unite with it. Others have so little relation that they will not unite with it without the intervention of a third body, which is called a base or mordant. This is a kind of intermediate affinity between the colouring matter and the fabric to which it is to be transferred, and renders the colouring matter insoluble in water.

The most usual base is alumine: the oxides of iron and tin are likewise used in combination with sulphuric, acetic, nitro-muriatic, and tartareous acid.

The ordinary mode of dying colours that require a base, is first to communicate the colour by dipping the fabric in the colouring solution, and afterwards to pass it through a solution of the base which fixes it.

In *calico printing* the mordant is mixed with a kind of paste; in this state it is applied to the surface of a wooden block, or pattern, which is then pressed upon the cloth. After the mordant is dry, the fabric is passed through the colouring matter, in solution. This becomes fixed in that part of the cloth which is covered with the base; and the colouring matter is so loosely held in the other parts that it readily washes out.

The great variety of colours which are produced by dying are reducible to four, viz. blue, yellow, red, and black.

Blue is obtained from indigo by steeping the plant in water; this produces a fermentation that deposits the colouring matter.

Indigo readily combines with most cloths without a mordant or base. This colouring matter may be employed in its simple oxygenized state, with sulphuric acid, which gives an immediate blue; or its oxygen may be taken up by mixing it with lime; this communicates a green colour; but it absorbs oxygen from the atmosphere until it becomes of a dark blue.

Yellow dyes are chiefly formed of shumach, turmeric, and fustic, from which a variety of yellow colours are produced according to the matter and the mordant, whether it be alumine, oxide of iron, or tin. By the addition of indigo, green is produced.

The colouring substances for red, are cochineal, archil, madder, and Brazil wood: all these require mordants, which are sulphate of alumine and nitro-muriates of tin. With red and yellow, orange is produced, and with blue and red, purple.

Nut galls, which consist of gallic acid and tan, united with sulphate of iron, produce black; but to deepen the dye, logwood is added.

To print a white cloth with black spots, a paste is made with citric acid, and gum, or flour. This, by means of the wooden pattern, is spread over the whole of the fabric, saving those spots which are intended to be black. The cloth is then dipped in the black dye; but the colouring matter only combines with it in those parts or spots that have not been touched by the paste; this being done, the paste is washed off, and the black spots remain.

Animal Structure and Functions.

THE animal structure is the most complex and interesting subject of natural inquiry. So many striking and important functions are perpetually operating in this wonderful machine, that they could not fail to excite our wonder and attention, even if we were not conscious that our own health and feelings were involved in the research.

Our first object will be to point out the elements of which animal bodies are composed.

The constituent parts of animals chiefly consist of oxygen, hydrogen, nitrogen, carbon, phosphorus, lime, and sulphur: to these may be added a portion of iron, and some of the neutral salts.

These elements are variously combined, and form the different substances of the animal body: amongst the principal of these substances may be ranked Gelatine, or Animal Jelly, Albumen, Fibrine, and Blood.

Gelatine is contained in the tendons, cartilages, membranes, ligaments, and skin of animals. Isinglass, which is the product of a fish in Russia, being dissolved in water, shews all the properties of gelatine, or animal jelly. It may likewise be obtained from all the soft parts of animals by boiling, and even from bones. Gelatine constitutes the nutritious part of soups and jellies.

Albumen. The white of eggs consists chiefly of this substance; it forms the curd of milk, and likewise a considerable portion of the serum of the blood.

Albumen coagulates at the temperature of 150 degrees of Fahrenheit, and forms a dry transparent substance, like horn. It passes into a state of putrefaction by exposure to the atmosphere. It is the albuminous part of blood which clarifies sugar. The whites of eggs are generally used for clearing wine and many other fluids.

Albumen is insoluble in alcohol, oil, or water; but readily dissolves in alkalis. It has been stated that all animal substances are convertible into albumen and gelatine, and these two into soap and glue.

Fibrine is a white fibrous substance, which forms a principal portion of the muscular or fleshy part of animals. It is likewise found in the coagulum of blood. Fibrine is insoluble in water and alcohol; but is dissolved by acids and alkalis.

Fourcroy, and others, have observed that the muscular parts of animals are, under particular circumstances, converted into a concrete inflammable mass, much resembling spermaceti. On opening graves in different places, bodies have been found converted into a mass of fatty matter. The same has been observed of the flesh of quadrupeds, which have been kept under water for a certain length of time; and indeed it has been proposed to convert the muscles of dead animals into this fatty substance, to be used as spermaceti for making candles or soap.

Blood, which is so essential to life, varies considerably in different animals. In the generality of them it is of a red colour: but in some small animals this circulating fluid is nearly transparent. It likewise varies greatly in temperature. The blood of man, quadrupeds, and birds, is hotter than the atmosphere or medium in which they live; therefore they are called warm blooded animals. In fishes and reptiles it is nearly of the same temperature as the water or air in which they exist; on this account they have been called cold blooded animals.

When blood is first drawn from a vein it appears to be a homogeneous red fluid, which consolidates as it cools: in a short time we perceive a yellowish watery liquor separating from it, and the red mass increases in density according to the quantity of fluid which is given out. The fluid part is called the serum, and the solid part the crassimentum.

The serum, or albuminous matter, is soluble in cold water; but coagulates at an increased temperature. When exposed to the atmosphere it soon passes into a putrefactive state.

The crassimentum being washed in water, separates again into two distinct substances, one of which is composed of red globules that tinge the water of a red colour; the other is an insoluble white fibrous mass.

The blood of most animals contains a considerable portion of ferruginous matter, from which iron has been obtained in its metallic state.

The difference of colour between the arterial and venous blood in the same animal, is supposed to arise from the oxydizement of the iron by the oxygen of the air contained in the lungs.

Before the structure of the human body is considered, it may be necessary to give a definition of some of the most remarkable parts that compose it.

Bones are hard substances which form the frame work of the body.

Cartilages are firm smooth elastic masses, that cover the ends of the bones.

Muscles are contractile and expansible organs, which are attached to the bones, and give motion to the various parts of the body.

Tendons are tough white shining cords, by means of which the muscles are fastened to the bones.

Ligaments are strong tendinous bands that connect bones to each other.

Blood-vessels are flexible membranous tubes through which the blood is circulated.

Lymphatics are transparent membranous tubes through which the absorbed fluids are conveyed.

Nerves are white cords connected with the brain, and are the instruments of sensation and volition.

Glands are organs employed for the purpose of secretion.

The structure of animals manifests great design and contrivance, not only in the general mechanism of their bodies, but likewise in the peculiar adaptations of the form of each species to its respective station. The human body, as the receptacle of a divine spirit, is particularly distinguished above all others for its admirable structure: the form is peculiar to itself; yet in its functions the general analogies of nature are obvious. Many of the mechanical motions which it possesses, are however, exclusively its own, and excellently calculated for a more perfect state of animal being.

The construction and action of the body would alone be sufficient to convince a rational mind of the existence of an Omniscient Being. How admirable are all the organs of sensation: not only for the high gratification which the mind receives through their medium, but for their exquisite contrivance and advantageous situations, whether for use or security. Could the eyes be more conveniently placed?—From their elevated situation and flexible motion, they are capable of receiving visual impressions from an extended horizon, without any collateral effort; and the delicate construction and important use of these organs are, by the same wisdom, secured from injury by the bony orbit that nearly surrounds them, the lids that shield them, and the secretions that wash off all irritating substances from their surfaces. The interior construction, by which the rays of light are conducted to the optic nerve, is likewise of most exquisite design; and every other organ of the animal machine is equally an object of admiration, whether we regard its use or construction.

Bones may be considered as the basis of the body on which the other parts depend for situation and support; consequently they will properly form the commencement of this general view of the animal structure and functions.

Bones consist of fibres which are distributed in plates: these plates are not closely applied to each other, but admit the intervention of transverse fibres which constitute cells.

All bones are cellular, but the porosity varies in different parts of the same bone; on the surface the cells are so small as to be scarcely perceptible, but they conspicuously increase in magnitude towards the centre.

The marrow which fills the cavities of bones is an oil contained in the cells of a fine transparent membrane that receives numerous blood-vessels. It has different appearances in different bones, and even varies in the same bone at different ages. In youth it is very fluid and reddish; in middle life it becomes whiter and of a thicker consistence; and in old age it is thin and watery.

In some instances bones are immoveably joined together, as the bones of the head, which are united together by serrated edges; the indentations receiving each other alternately. The articulation of the teeth is another instance of immoveable union; which, in its principle, is similar to that by which a nail driven into a piece of wood remains fixed in it.

The moveable joints are covered with smooth cartilages, by which the friction arising from their action is considerably diminished: this is still further reduced by the secretion of a lubricating fluid, called synovia, which is retained between the extremities of the bones by capsular ligaments.

The moveable bones are kept in their proper situations by strong ligaments, which pass from one bone to the other.

Bones have irregular surfaces, by means of which the muscles are the more firmly attached to them.

Although the bones which constitute the human skeleton do not stand perpendicular when the body is in an erect position; yet a line drawn from the common centre of gravity would fall in the middle of the common base which they form: this not only gives great stability to the body, but likewise more ease and strength than it would obtain if the bones had been placed in lines perpendicular to the horizon.

The hard part of bones of warm blooded animals consists of phosphate of lime. The shells of cold blooded animals are formed of carbonate of lime.

Muscles are soft contractile fibrous masses, formed of a pulpy substance, enveloped in cellular membrane. By what means the mind operates on those organs so as to produce motion, is unknown.

Muscles when submitted to chemical analysis, afford water, empyreumatic oil, nitrogen gas, carbonate of ammonia, and a coal, containing a small portion of fixed alkali.

For the purposes of growth, repair, and sensation, muscles are abundantly supplied with arteries, veins, absorbents, and nerves.

On the surface, and in the interstices of muscles, fat is deposited, contained in the cells of that loose substance, called cellular membrane, which universally envelopes them. By this arrangement, a beautiful smoothness is given to the surface of the body, and a supply is preserved for the support of the animal, when a sufficient quantity of food is not furnished by the organs of digestion.

Fat is an animal oil, inflammable, and differing from marrow only in its density. It contains an acid, called the sebacic, which, when highly concentrated, is said to exhibit the same properties as the acetic acid.

The exterior covering of the human body consists of three parts, the *Cutis* or *true skin*, the *Mucous Membrane*, and the *Epidermis, external* or *Scarf-skin.*

The arteries of the true skin are of a small diameter, but very numerous; the veins are of much larger dimensions. From the extremities of arteries, called exhalants, perpiration exudes, the quantity of which is found to exceed that of all the other collected secretions of the body. The extremities of the nerves of touch are also so generally distributed throughout the cutis, that the point of the finest needle cannot be brought in contact with any part of it without exciting an instant sensation.

The cutis abounds with gelatine, and in the art of combining tan with this substance, the process of making leather consists.

The colour of different nations is produced by that of the mucous membrane, which lies immediately upon the cutis and beneath the epidermis. In the African, it is black, in the American, of reddish hue, in the European, of a yellowish pink colour. On analysis, it yields carbon, albumen, ammonia, and water. The peculiar whiteness of albinoes is said to be occasioned by a total deficiency of this mucous membrane.

The epidermis is an insensible, semi-transparent, reticulated, membrane, covering the whole body; it shields the extremities of the nerves and blood-vessels distributed on the cutis, from the painful or injurious contact of irritating substances, and gives a smoothness and beauty to every part. It is formed, like all other parts, by the blood-vessels; but when formed, their tubes can no longer be traced in it. It is chiefly composed of albumen.

All the parts we have described are formed and supported by the blood. It remains to shew from what sources this important fluid is itself derived, and by what means it is so generally diffused throughout the system.

The food of animals, after having been masticated and mixed with saliva, is admitted into the stomach, where a process takes place, which the art of chemistry cannot in any degree imitate, namely, digestion. The food in the stomach is first converted into a greyish coloured fluid called chyme, which, after passing into the upper part of the intestinal canal, is separated from its grosser parts, assumes the appearance of milk, and is called chyle: In this state it is taken up by a number of absorbent vessels, called lacteals, which, uniting in one trunk, convey it to a large vein which communicates with the heart. The gross remainder of the food proceeding through the intestinal canal, which is one continuous tube, is then naturally discharged.

The secretions of the stomach and pancreas, aided by the heat of the body, are supposed to be the chief agents in the wonderful formation of chyle. It is known that the stomach secretes a fluid, called the gastric juice, which has the property of coagulating milk; and it is also ascertained that milk, when received into the stomach, is always coagulated before it is digested; but here our knowledge terminates.

The gastric juice when analyzed yields gelatine, phosphate of soda, and water; but these results will not account, according to chemical principles, for the effect which may every day be observed in the process of making cheese, where the small quantity of gastric fluid contained in a piece of the stomach of a calf, is found sufficient to coagulate a large vessel full of milk. The subsequent changes produced on digested food, are still less understood.

The *heart* of warm blooded animals may be compared to a muscular bag, divided into four cavities, viz. two auricles and two ventricles. The auricles receive blood from the veins, and transmit it to the ventricles, the sides of which contract and propel it into the arteries which arise from them. Each auricle is separated from its ventricle by a curiously constructed valve, which readily permits the blood to pass into the ventricle, but effectually prevents its return; so that when the ventricle contracts, it is necessarily forced into the tube of the artery which is open to receive it, and through which it performs its destined circulation.

The heart may be considered as a double organ, each auricle and ventricle performing a separate circulation. To explain the use of this structure, it is requisite, first, to give a short description of the *lungs*.

When we inspire, a volume of air passes down the trachea, or wind-pipe, and inflates a great number of membraneous cells, the sides of which are covered with the branches of arteries. These cells, connected together by cellular membrane, form collectively the organ called the lungs. In expiration, the air received is again expelled.

The *blood* which has circulated through the body is returned by the veins to the right auricle of the heart, but greatly altered in its colour and qualities; its scarlet hue is changed to purplish black, and it is no longer capable of supporting the vital functions. To restore its lost qualities it must undergo a chemical change by being exposed to the action of the atmospheric air. For this purpose it is transmitted from the right auricle of the heart into the right ventricle, from whence it is propelled into a vessel, called the pulmonary artery, the branches of which ramify on the cells of the lungs. Through the coats of these arteries the inspired air operates the necessary change. The blood recovers in those vessels its vivid colour and lost properties, and is again rendered fit for the functions of life. In this renovated state it passes through the pulmonary veins to the left auricle of the heart, is received into the left ventricle, and from thence it is transmitted through the large artery, called the aorta, to be distributed for the support of the whole body.

In man, the quantity of blood transmitted through the pulmonary artery is equal to that which passes through the aorta; and the surface of the cells of the lungs taken collectively is equal to that of the exterior surface of the whole body.

To account for the change effected in the blood, by passing through the vessels of the lungs, let us examine whether the inhaled air contained in their cells undergoes any correspondent alteration. The air we breathe is composed of oxygen, nitrogen, and a small quantity of carbonic acid gas; but this air, when respired, is found to have lost nearly the whole of its oxygen, and to have acquired a considerable addition of carbonic acid gas; its nitrogen remaining undiminished. The renovation of the colour and properties of the blood is also found chiefly to depend on the oxygen which it has abstracted from the inhaled air. Dr. Priestly has shewn that if venous blood be enclosed in a bladder, and placed in oxygen gas, it will regain its florid colour; the oxygen will be diminished in quantity, and the weight of the blood will be encreased according to the weight of the gas which has disappeared.

Animals cannot exist in air deprived of its oxygen, and if killed by confining them for a few minutes in de-oxygenized air, all the blood which they possess will be found of the dark venous colour.

From these experiments the disappearance of the oxygen in respired air is satisfactorily explained; but the additional quantity of carbonic acid gas contained in it, is not so readily accounted for. It is conjectured by some, that a quantity of hydro-carbonaceous matter is given out by the venous blood, and that all the oxygen inhaled, does not combine with the arterial blood, but that a portion of it, uniting with the hydrogen, forms water, and constitutes the moist vapour of the breath; and that another portion, uniting with the carbon, forms the carbonic acid. The quantity of carbonic acid gas in respired air is found to be about ten times greater than the air inhaled contains.

Different classes of animals have different degrees of natural heat. And it is known that animals of the highest natural temperature decompose in their lungs the greatest quantity of air. Toads have been found alive enclosed in blocks of marble, where they must have been imprisoned many years, totally excluded from air; but the blood of these animals never exceeds the temperature of the medium in which they exist. On the contrary, the blood of the larger animals, and of man especially, preserves its natural heat, which is about 96 Fahrenheit, in all temperatures, whilst the powers of life are vigorous. It is supposed that the decomposition of air in the lungs is the source of animal heat. Oxygen gas being composed of oxygen and caloric, it is presumed that when the oxygen combines with the blood, the caloric is disengaged and diffused throughout the system. Dr. Craufurd has endeavoured to prove that the air and vapour discharged from the lungs do not contain more than one-third part of the absolute heat of the air inspired; consequently, that a considerable quantity of heat is actually acquired by the system at each inspiration: but it has been objected, that if animal heat were really produced in this manner, the temperature of the lungs would be greater than that of any other part of the body, which is found not to be the fact. This objection, however, is not conclusive. The heat evolved in the lungs may be conveyed throughout the system by some adequate means as yet unknown.

By what process the glands of animals, such as the liver, pancreas, &c. effect their several secretions is a subject too intricate and too imperfectly understood to be discussed in a work professedly introductory. It is only necessary to say, that in each of those organs, as far as their structure and functions have been investigated, the power and wisdom of the great artist are wonderfully apparent. And for the benefit of mankind, it is earnestly to be hoped that the progress of chemical science may contribute to elucidate this important part of physiological knowledge.

Of the functions of the brain still less is known. It is the organ of perception and volition, and, in man, the residence of an immortal spirit. The nerves are also known to be its channels of communication. But by what process external impressions are conveyed or perceived, or the determinations of the mind formed or transmitted, is a mystery probably never to be revealed to the limited faculties of man in his present state of existence.

During the printing of the present work, Professor Davy has published an opinion respecting oxymuriatic acid, which, if it should be established, will tend to produce a remarkable change in the whole theory of Chemistry.

It has been considered by the French chemists Lavoisier and Fourcroy, that oxymuriatic acid is a supersaturation of muriatic acid with oxygen. Mr. Davy is endeavouring to shew that oxymuriatic gas, which is the pure form of this acid, is not an oxygenated state, nor does it contain any muriatic acid; but that it is a new and distinct element of nature, incapable of oxydizing metals; and that when it is united with hydrogen, it constitutes muriatic acid.

J. Poole, Printer, Taunton.

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